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U. S. WAR DEPARTMENT

TECHNICAL MANUAL

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AIRPLANE HYDRAULIC SYSTEMS
AND
MISCELLANEOUS EQUIPMENT

Oct. 29, 1940

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WAR DEPARTMENT,
WASHINGTON, *October 29, 1940.*

AIRPLANE HYDRAULIC SYSTEMS AND MISCELLANEOUS EQUIPMENT

Prepared under direction of the
Chief of the Air Corps

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SECTION I

HYDRAULIC PRINCIPLES

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1. General.—In a study of hydraulics as applied to aircraft hydraulic systems, two of the basic principles of liquids must be considered.

a. Liquids are practically incompressible. A pressure of 100 pounds per square inch applied to a body of water causes it to lose only about 0.0003 of its original volume. Liquids, such as the oils and other fluids used in hydraulic systems, vary slightly from this figure but for all practical purposes their compressibility is negligible.

b. Pressure applied anywhere to a body of confined or enclosed fluid is transmitted with undiminished force in every direction (Pascal's law). This pressure acts at right angles to every portion of the surface of the containers with equal force on equal areas.

2. Application of hydraulic principles.—*a.* Because of the incompressibility of liquids they can be used to transmit a force. A

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simple demonstration of this may be illustrated by placing a stopper in one end of an iron pipe and completely filling the pipe with water. A second stopper is placed in the open end and a force is exerted on this second stopper. This force is transmitted through the liquid and forces the first stopper out of the pipe.

b. In his experiments Pascal found that a force of 1 pound pushing against a small piston will equal a force of 10 pounds pushing against a large piston, the area of which was 10 times that of the small piston. This is illustrated in figure 1.

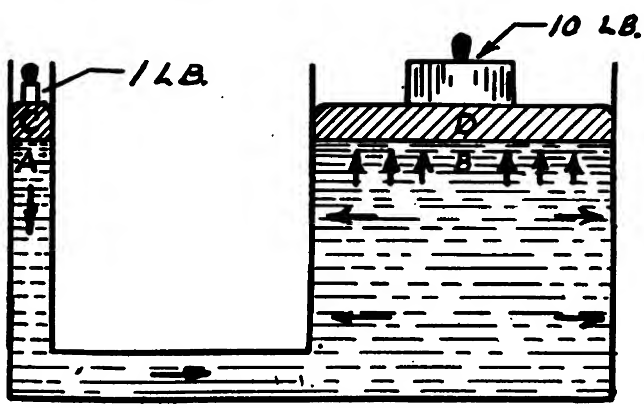

FIGURE 1.—Multiplication of force (hydraulically).

c. It follows from Pascal's law that a force slightly in excess of 1 pound pushing against the small piston will move the large piston against which 10 pounds is pushing. This constitutes a mechanical advantage comparable to that shown in figure 2, and may be used for many practical purposes, e. g., hydraulic jack, hydraulic press, etc. One important fact, however, must not be overlooked.

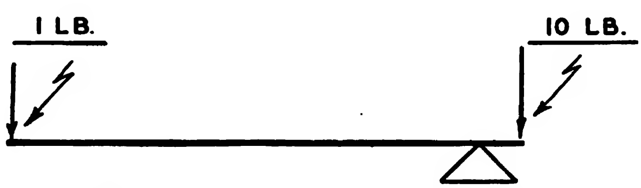

FIGURE 2.—Multiplication of force (mechanically).

The amount (volume) of fluid forced out of the small cylinder (fig. 1) is exactly equal to the amount of fluid forced into the large cylinder. A definite volume of fluid has been transferred from one cylinder to another, therefore, the small piston must travel a greater distance than the large one in the same length of time. In other words, what is gained in force is lost in speed.

d. The foregoing principles of hydraulics may be applied to advantage in operating certain mechanisms on an airplane. Since a

confined fluid will transmit a force, light oil may be conducted in tubing from one point to another on an airplane between which two points it is desirable to transmit a force. The force applied to the liquid at one end of the tube will be transmitted to the other end regardless of the length of the tube or the number of bends. Furthermore, by expanding the bore of the tube on one end and inserting a piston into this expanded section, the force applied at the small end of the tube will be increased at the large end. The increase in force will be in direct proportion to the expansion of the tube. Oil forced into the tube at the small end at a certain rate will move the piston at the large end at a proportionately slower rate but with an increased force applied against it. The pressure in pounds per square inch will be the same at both ends of the tube. By means of a piston rod, the motion of the piston, and the force exerted on it, may be transmitted to the mechanism to be operated. This application of hydraulic principles is the keynote of the operation of hydraulic systems installed in airplanes. For the hydraulic units commonly employed in airplane hydraulic systems see Section II.

Section II

HYDRAULIC SYSTEM UNITS

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Pressure gage snubber	23
Bleed	24

3. General.—*a.* A unit of hydraulic equipment is a part of the hydraulic system having a distinct function to perform.

b. The names of the several units are generally suggestive of the functions performed by them. Some have names long associated with airplane equipment; a considerable number, however, have names of relatively recent origin.

c. The units discussed in this section are representative of the hydraulic units now in general use. Each of the units treated in the discussion is taken as representative of the simplest device that will

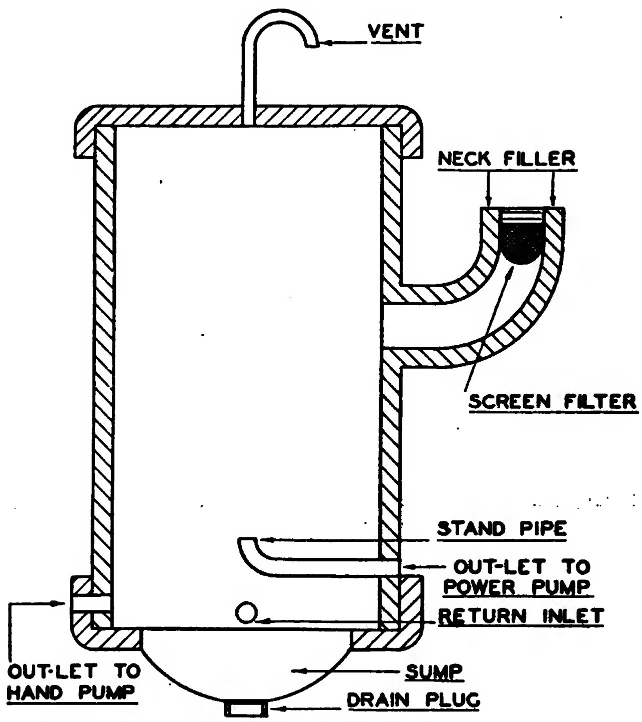


FIGURE 3.—Reservoir.

completely perform the related function. The figures are designed to illustrate the discussion and are not intended to be detail drawings of the units.

4. Reservoir.—*a.* The reservoir (fig. 3) houses the supply of fluid for the hydraulic system. Fluid is drawn from the reservoir by the hydraulic pumps, forced by them throughout the system, and eventually returned to the reservoir. The reservoir is the unit through which fluid is introduced into the hydraulic system. Not only does the reservoir supply the operating needs of the system, it also replenishes fluid lost through leakage and seepage. Furthermore, the reservoir serves as an overflow basin to receive the excess of fluid forced out of the system by temperature expansion and by

piston rod displacement. The reservoir also affords an opportunity for the fluid to purge itself of air bubbles induced into the system by certain operating units. Foreign particles and solids picked up in the system are deposited in the reservoir.

b. Reservoirs are always vented to the atmosphere. The vent line is led overboard and the excess fluid is thereby disposed of. A filter

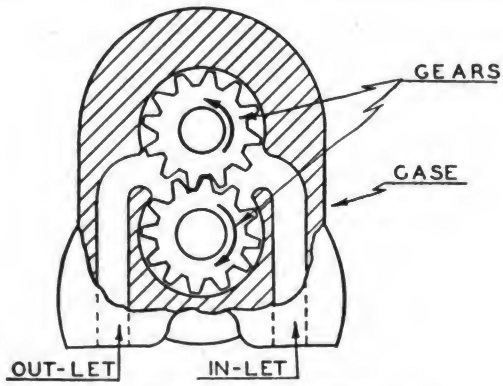


FIGURE 4.—Gear type power pump.

screen may be provided in the filler neck and a sediment trap is located at the lowest point in the reservoir. A standpipe is installed in the reservoir to insure that the hand pump is fed, even though the fluid supply has been depleted to the point of starving the power pump. A fluid quantity gage is sometimes installed as an accessory and may be used as a guide in filling the reservoir. In most cases,

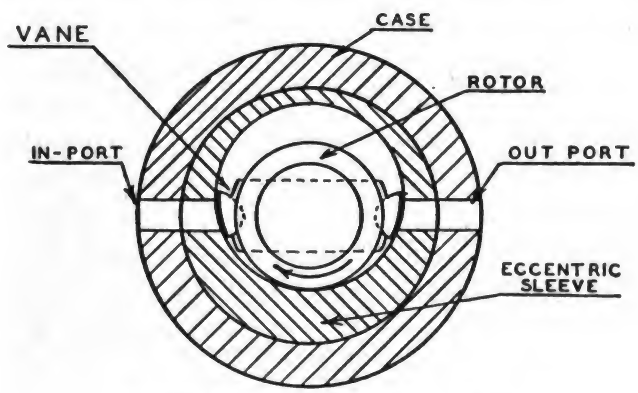


FIGURE 5.—Vane type power pump.

however, the reservoir is simply filled to overflowing. The reservoir is usually located in the system at a higher level than the pump so as to keep the pump primed at all times.

5. Power pump.—*a.* A power pump is the energizing unit of the hydraulic system. It is the unit with which circulation of the fluid is induced and working pressures developed. The power pump draws fluid from the reservoir and forces it throughout the hydraulic system.

b. A power pump may be engine driven, in which case it is mounted on the accessory section of the engine crankcase, or it may be driven by an electric motor and mounted in any convenient location, usually near the reservoir. The pump may be of the gear type, or it may be of the vane or gerotor types (see figs. 4, 5, and 6). In any case, only a small volume of fluid is passed per revolution of the pump. Due to the close clearances common in hydraulic pumps, very high pressures may be obtained from them. The capacities of the hydraulic pumps in general use vary from 1½ to 3 gallons per

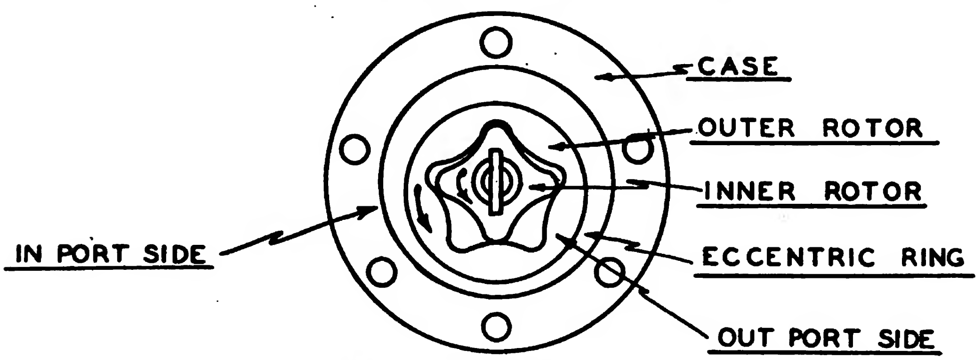
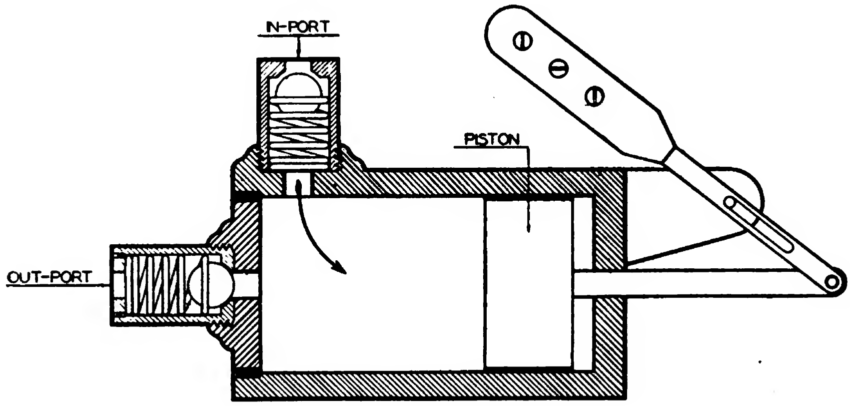


FIGURE 6.—Gerotor type power pump.

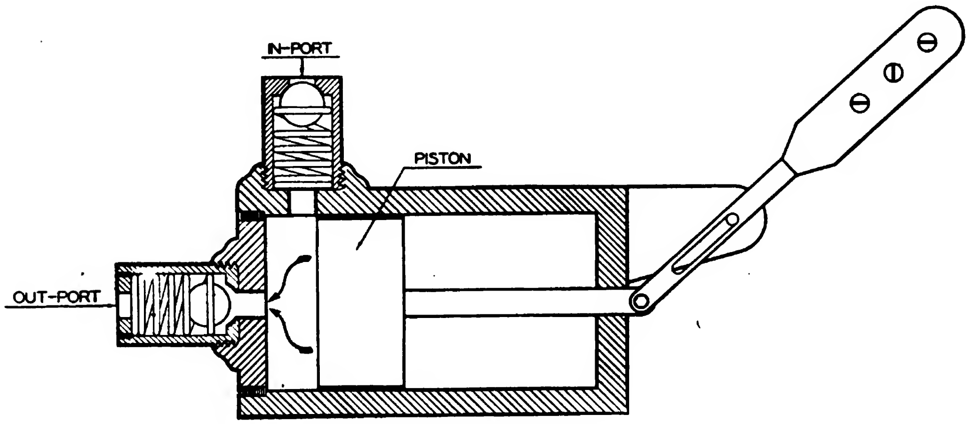
minute. Maximum working pressures of 1,600 pounds per square inch are obtainable. The smaller capacity pumps absorb approximately 1½ horsepower at full load and the larger ones approximately 3 horsepower to operate them. Most power pumps have a shear pin incorporated in the drive mechanism. This is to free the pump and prevent injury to the system in case of failure of the system relief valve. Power pumps are not intended to operate at peak loads for periods in excess of 4 to 5 minutes. A power pump is a very specialized piece of equipment and should not be tampered with except by specially trained personnel.

6. Hand pump.—*a.* A hand pump is intended to serve as a substitute for the power pump during emergencies in flight and also as a source of power for checking the hydraulic system when the airplane is at rest on the ground. It is fed from the reservoir and discharges into the pressure manifold.

b. The hand pump is a manually operated reciprocating piston type pump. It may be of the single-action type (fig. 7) or it may be of the double-action type (fig. 8). In either case check valves are required on the inport and on the outport sides of the pump. The



① Suction stroke.

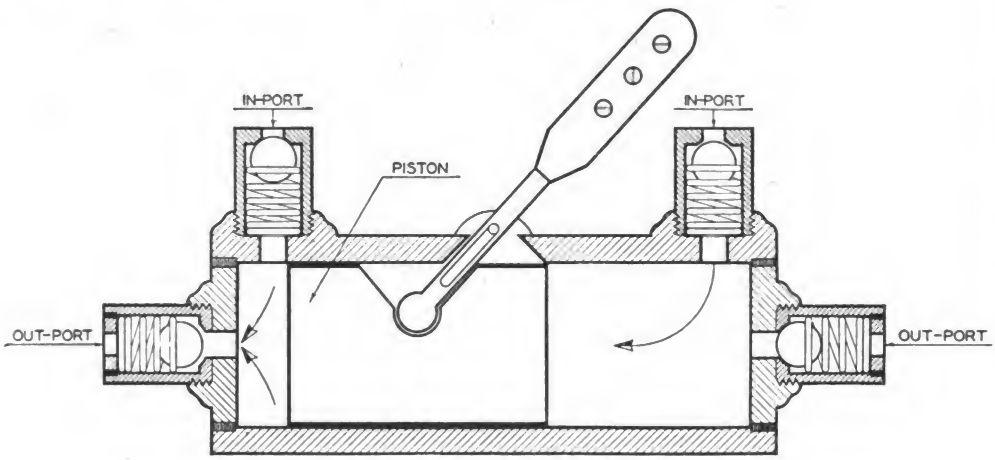


② Power stroke.

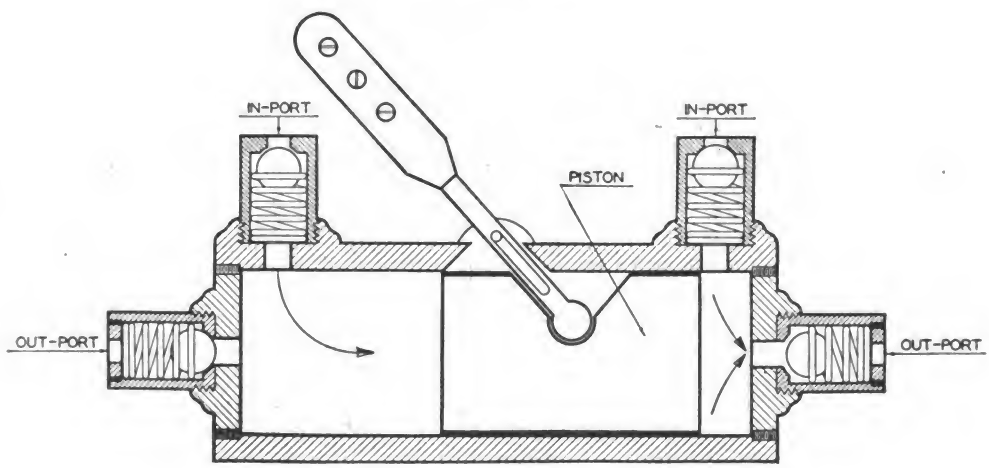
FIGURE 7.—Single-action hand pump.

check valve on the inport side prevents fluid under pressure in the pump cylinder from flowing back to the reservoir. The check valve on the outport side prevents fluid from being sucked into the pump from the pressure manifold. The hand pump is always located so that the handle is readily accessible to the pilot and also to members of the crew. The handle of the pump is of such length and the piston is of such area that working pressures may be developed without undue exertion on the part of the operator. Pressures of 2,500 pounds per square inch are obtainable with some hand pumps. A

check valve is usually placed in the pressure manifold upstream from the point where the hand pump discharges into the manifold. This is to concentrate the output of the hand pump into that section of the hydraulic system where it will insure operation of the mechanism in case of failure of power pump.



① Stroke one.



② Stroke two.

FIGURE 8.—Double-action hand pump.

7. Pressure manfiold.—*a.* The pressure manifold conducts fluid from the hydraulic pumps to the control valves. The pressure tank, pressure regulator, system relief valve, etc., are part of or auxiliary to the pressure manifold. It is the main line of the pressure side of the hydraulic system.

b. The pressure manifold as illustrated in figure 9 may consist of a prefabricated branching tube or it may consist of an assembly of tubes and fittings. It may be very short, or it may be several feet in length.

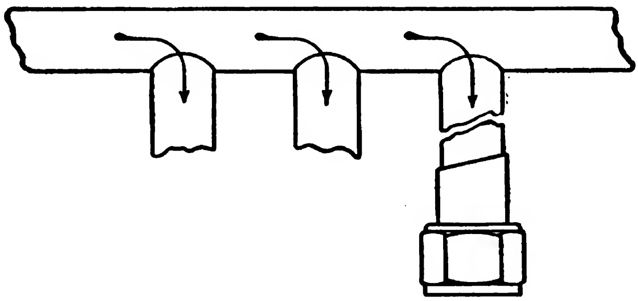


FIGURE 9.—Pressure manifold.

8. Surge chamber.—*a.* A surge chamber is a device for modulating pressure surges in the hydraulic system. When the pressure is on the increase, air or a spring is compressed; as the pressure recedes, the compressed air or spring expands. Thus, sudden pressure

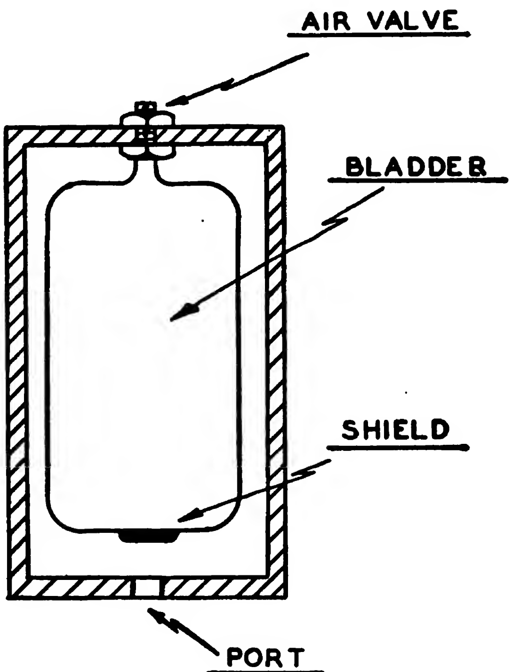


FIGURE 10.—Bladder type surge chamber.

increases that might otherwise impose destructive stresses on the hydraulic system are damped out.

b. Surge chambers may contain an inflatable rubber bladder, or in some cases, a coiled spring and piston. Surge chambers are

mounted into the pressure side of the system, often as an adjunct to a relief valve or a power-control valve. The two types mentioned above are illustrated in figures 10 and 11.

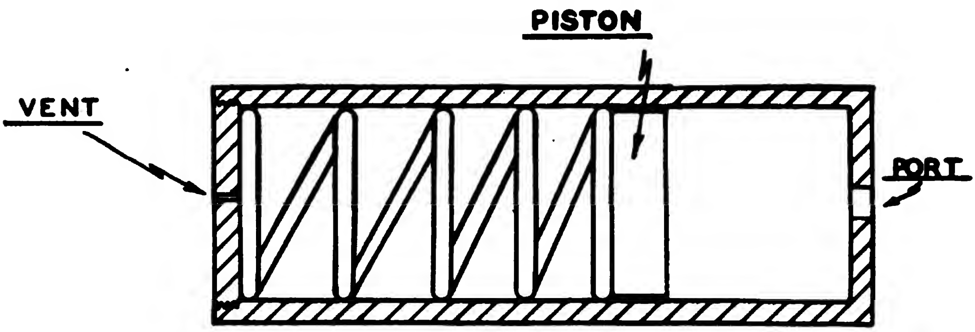


FIGURE 11.—Spring type surge chamber.

9. Pressure tank.—*a.* A pressure tank, or "accumulator" as shown in figure 12, is essentially a very large surge chamber. In addition, however, to damping out pressure surges, a pressure tank is intended to serve as an energy storage device. Under circumstances when the system does not require the total output of the power pump, the excess fluid is forced into the pressure tank. The air in the pressure tank is compressed by the incoming fluid and absorbs and stores

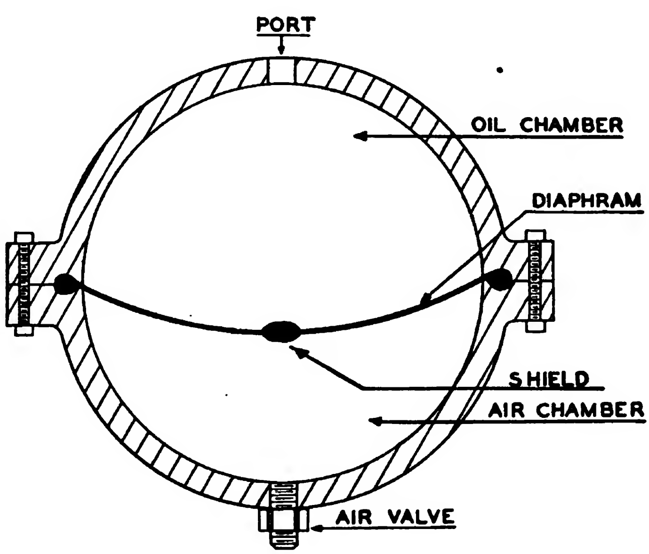
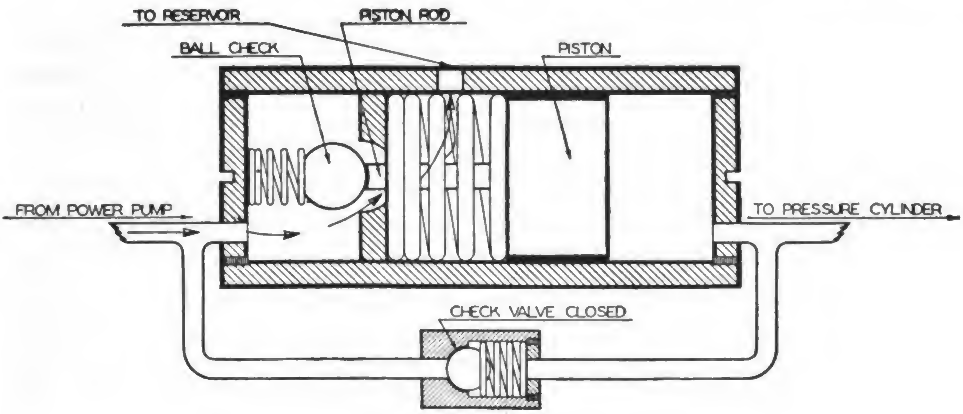


FIGURE 12.—Pressure tank.

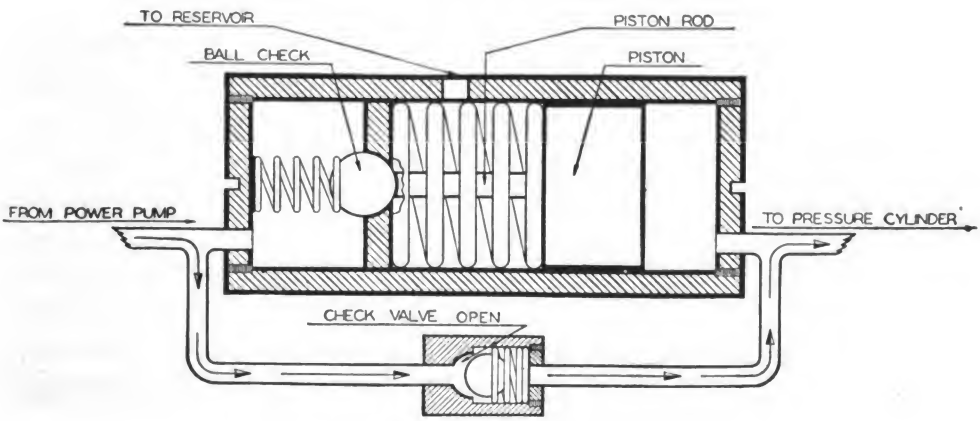
the energy required to compress it. When the output of the power pump falls below the requirements of the hydraulic system, the compressed air in the pressure tank forces fluid back into the pressure manifold. This fluid is returned to the pressure manifold under pressure and in sufficient quantities to operate the mechanism for a

limited time. The pressure tank ordinarily supplements the power pump at periods of peak load but may also serve as the motivating force during emergencies in flight and during landing when the power pump is inactive or operating at a decreased r. p. m.

b. Pressure tanks are built to withstand high pressures and to contain considerable quantities of fluid. The tank is divided into two compartments, an air compartment and a fluid compartment. The two compartments are separated by a piston or by a synthetic rubber



① Valve open.



② Valve closed.

FIGURE 13.—Pressure regulator.

diaphragm. The air compartment is equipped with an air value for charging the tank with compressed air. By serving the tank with an initial charge of air it assures that the total fluid output of the tank will be at sufficiently high pressures. The pressure tank is usually located near the pressure manifold of which it is an adjunct.

10. Pressure regulator.—*a.* A pressure regulator is, as the name implies, a device for regulating pressures. When the pressure in

the pressure manifold attains the upper limit of the pressure range for which the regulator is adjusted, a valve opens and the output of the power pump is bypassed back to the reservoir. When the pressure in the pressure manifold drops to the lower limit of the predetermined range, the valve closes and the output of the pump is directed into the pressure manifold. The range of pressures for which the regulator is set to pass fluid into the pressure manifold is relatively broad, in some cases 25 percent of the maximum working pressure. A pressure regulator operates very much as a relief valve except that its control of pressure is over a much wider range and the valve is held open by system pressure instead of pump pressure. This permits the power pump to operate without load after working pressure has been attained and throughout those periods when the output of the power pump is not required to operate mechanism.

b. The principle of operation of a pressure regulator is shown in figure 13. The regulator consists of several chambers. In one end of the unit is a relief valve. In the opposite end of the unit is a piston. Between the two is the bypass chamber. Fluid enters the valve end of the unit from the power pump and, since the spring loaded valve is closed, the fluid continues on to the opposite end of the unit and thence into the pressure manifold. Fluid flows from one end of the unit to the other through a shunt line which includes a check valve. As pressure builds up in the pressure manifold and in the pressure regulator, the pressure of the fluid on the piston impels it to move inward until the piston rod attached to the inner side of the piston rests against the spring loaded valve. When the fluid pressure attains the upper limit of the pressure range for which the regulator is adjusted to operate, the force developed by the pressure of the fluid on the piston overcomes the combined force of the fluid pressure plus the spring tension exerted against the valve to hold it closed, and the valve is pushed off its seat. The output of the pump is now diverted through the open valve, thence through the bypass outlet and back to the reservoir. The check valve in the shunt line prevents the fluid under pressure in the pressure manifold from escaping through the open valve and bypass. The valve remains open and the output of the pump is circulated freely to the reservoir as long as the pressure in the pressure manifold is sufficient to hold the valve open. In case the pressure in the pressure manifold drops below the lower limit of the pressure range for which the regulator is adjusted to operate, the pressure on the valve plus the tension of the spring overcomes the weakened force on the piston and the valve closes. The output of the pump is now directed into the pressure

manifold again. The pressure regulator is always located at the extreme upstream end of the pressure manifold.

11. Relief valve.—*a.* The function of a relief valve is to release pressure in some section of the hydraulic system when such pressure has attained a predetermined value. Several relief valves may be required in a hydraulic system, each serving some particular section

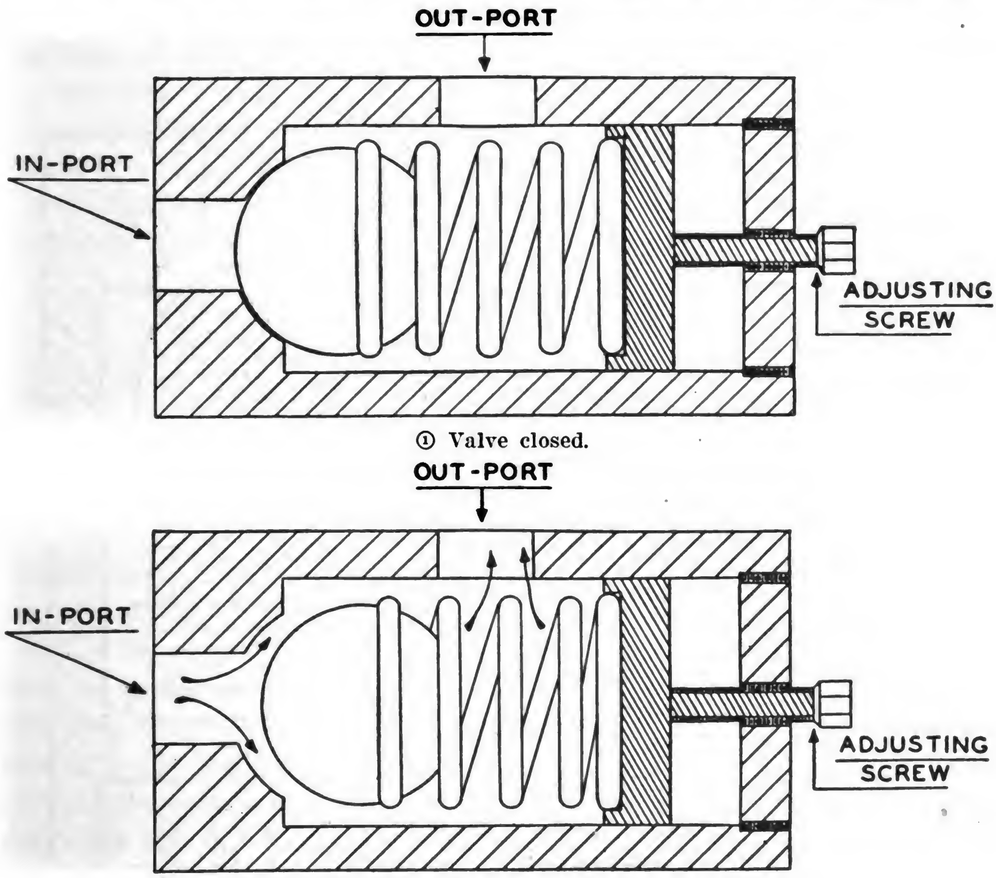


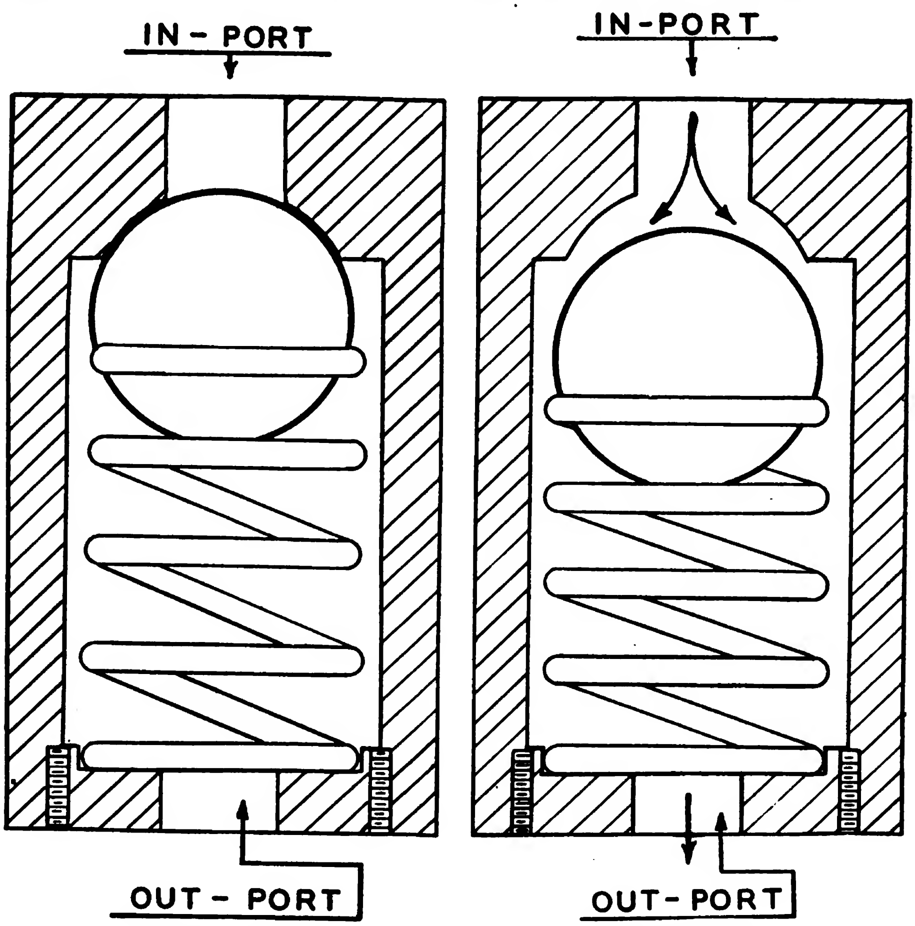
FIGURE 14.—Relief valve.

of the system. In such cases, it is not uncommon to have the different valves set to open at different pressures. The pressure for which a relief valve is set to open will be well above the minimum pressure required to operate the mechanisms, but below a pressure estimated to be a safe operating pressure. When a relief valve is intended only to relieve pressures caused by increase of temperature, the valve is apt to be termed a temperature expansion valve. Such valves are set to open at relatively high pressures. In any case, a relief valve passes fluid from the pressure side of the system to the return side.

b. A relief valve (fig. 14) depends upon a coil spring to hold the valve closed. The pressure in the system must overcome the tension

of the spring to push the valve open. When the excess pressure has been released, the tension of the spring again closes the valve. The tension of the spring is controlled by an external adjustment provided for the purpose.

12. Check valve.—*a.* The function of a check valve is to confine fluid under pressure within some section of the hydraulic system. It prevents the fluid from reversing its normal direction of flow



① Valve closed. ② Valve open.

FIGURE 15.—Check valve.

and thereby prevents pressure from escaping into an adjacent section of the system. Check valves are used in both the pressure side of the system and in the return side.

b. The valve mechanism of a check valve is held to its seat by either a coiled spring as shown in figure 15, or by its own weight. In the latter case it is called a flap check. When the pressure on the downstream side of the valve exceeds that on the upstream side, the resultant unbalanced force seals the valve closed. When the

relative pressures are reversed the valve is forced open against the tension of the spring and fluid passes through. The tension of the spring is relatively weak and is intended to be barely sufficient to support the valve in its proper position. Ordinarily, no means of adjustment of the tension of this spring is provided.

13. Orifice.—An orifice in a hydraulic line is simply a restriction as illustrated in figure 16. The object of an orifice is to restrain the rate of flow of the fluid in the line. The mechanism actuated by the fluid is thus caused to move more slowly. An orifice is used in connection with mechanisms the movement of which would be too fast with an unrestrained flow.

14. Orifice check.—*a.* Since an orifice restrains the flow of fluid similarly in both directions, it cannot be used in those sections of

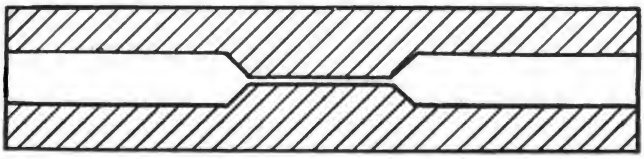
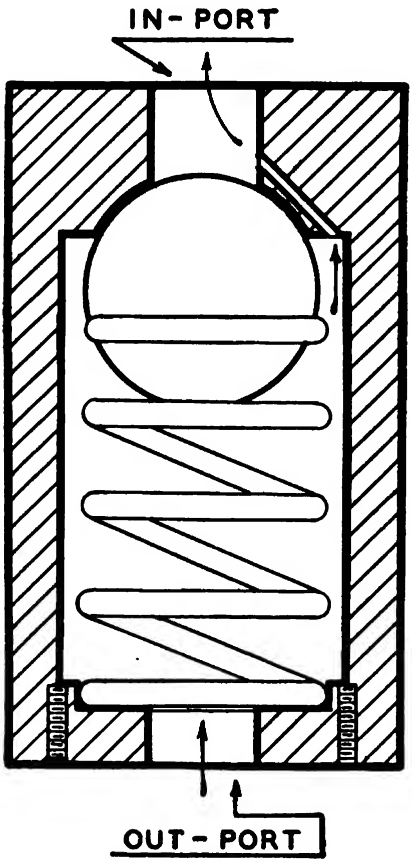


FIGURE 16.—Orifice.

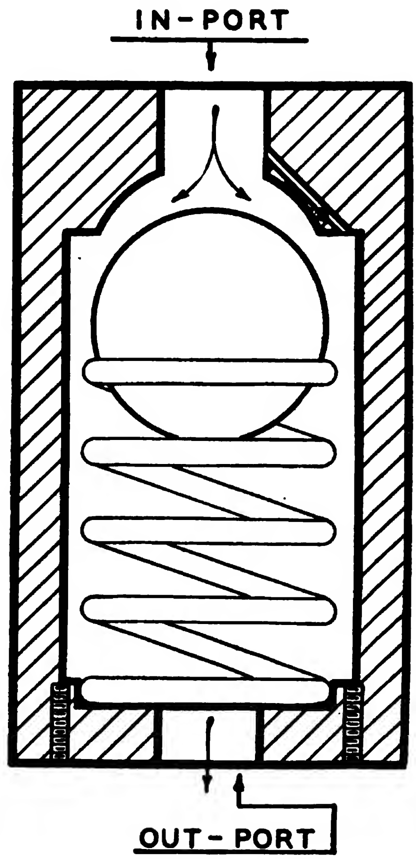
the system where it is required that the flow in one direction only be restrained. In such cases, a modified check valve called an orifice check is used.

b. In the case of an orifice check as shown in figure 17, the valve head is so formed as to prevent a perfect seal in its seat. In one direction the flow is unrestrained, while in the opposite direction the flow is restrained but not completely shut off. A common employment of an orifice check is in the wing flap system where it is desirable that the uptravel of the flaps be delayed against the tendency of the air pressure to force them up. Another employment of the orifice check is in the landing gear system to delay the extension of the gear against the tendency of the weight of the gear to pull it down too fast. An orifice check may be installed in either the upline or the downline to the actuating cylinder. The line in which it is installed and the direction in which it is installed in the line will determine which stroke of the mechanism is slowed up.

15. Bypass check.—A bypass check as illustrated in figure 18 is simply a check valve provided with a means whereby the valve may be manually opened to permit fluid to flow in either direction. The unit is usually employed in connection with a pressure tank so that the output of the hand pump may be diverted into the pressure tank. The normal setting of the valve is such as to concentrate the output of the hand pump into a restricted section of the pressure manifold. By moving a control lever which unseats the valve, a passage is provided whereby the output of the hand pump can reach the pressure tank. The bypass check is installed in the pressure



① Valve seated.

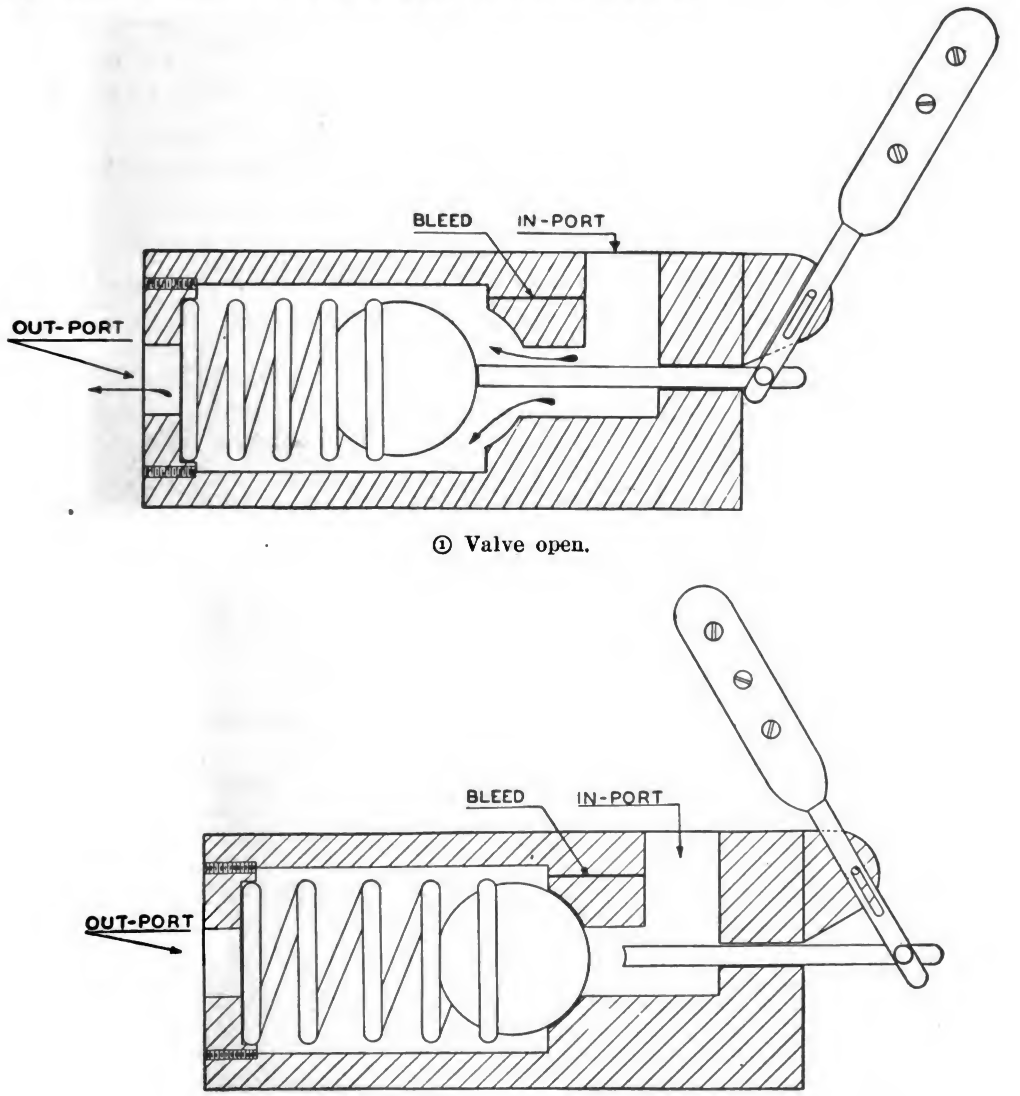


② Valve unseated.

FIGURE 17.—Orifice check valve.

manifold somewhere between the pressure tank and the point where the hand pump discharges into the manifold. The control lever is located accessible to the pilot or one of the crew.

16. Selector valve.—*a*. The selector valve is the control unit of the hydraulic system. The mechanism moved, the direction it is moved, and the distance it is moved are determined and controlled by manipulation of the selector valve or valves.



① Valve open.

② Valve closed.

FIGURE 18.—Bypass check valve.

b. There are three types of selector valves commonly used in hydraulic systems. They are the rotor type, the piston type, and the poppet type and are illustrated in figures 19, 20, and 21, respectively.

c. The rotor type selector valve is a four-port valve consisting of an inner rotor, an outer case, and a control handle. The four ports

in the case are spaced 90° apart. The rotor carries two fluid channels so arranged as to connect adjacent ports. When one port is connected to the pressure manifold, the opposite port is connected to the return manifold. The other two ports are connected to the actuating cylinder, one to one end of the cylinder and the other to the opposite end. It is thus seen that a rotation of 90° of the rotor changes the flow of fluid from one end of the actuating cylinder to the other end, thus reversing the direction of movement of the piston. The fluid purged from the actuating cylinder flows through the control valve and thence into the return manifold. In this type control valve, when one port is open, they are all open, and the valve is closed to the passage of fluid midway between port openings. This midport setting of the control valve may be used when it is desirable

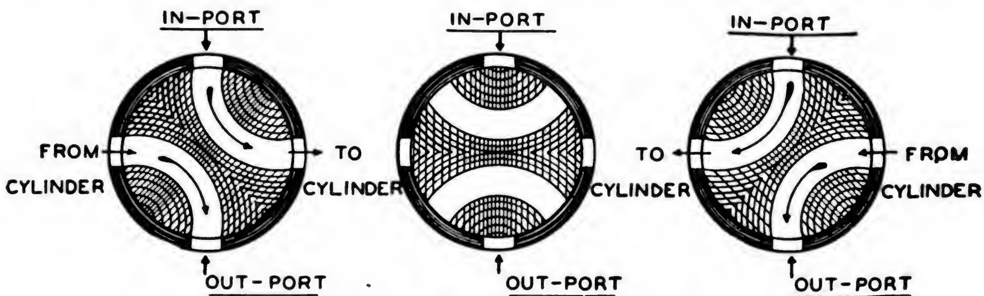


FIGURE 19.—Rotor type selector valve.

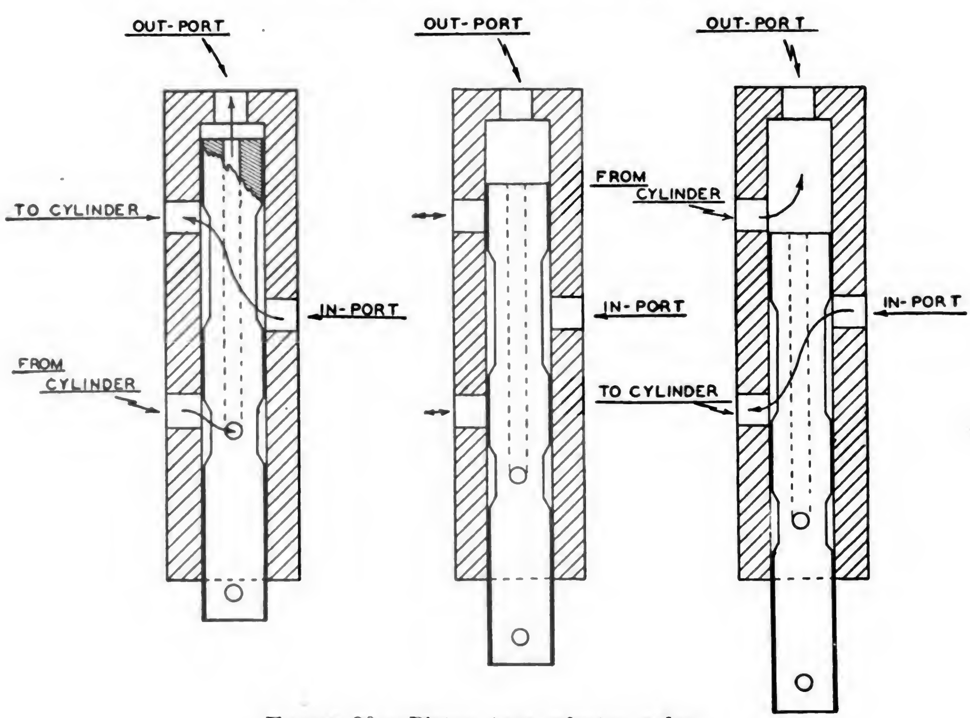


FIGURE 20.—Piston type selector valve.

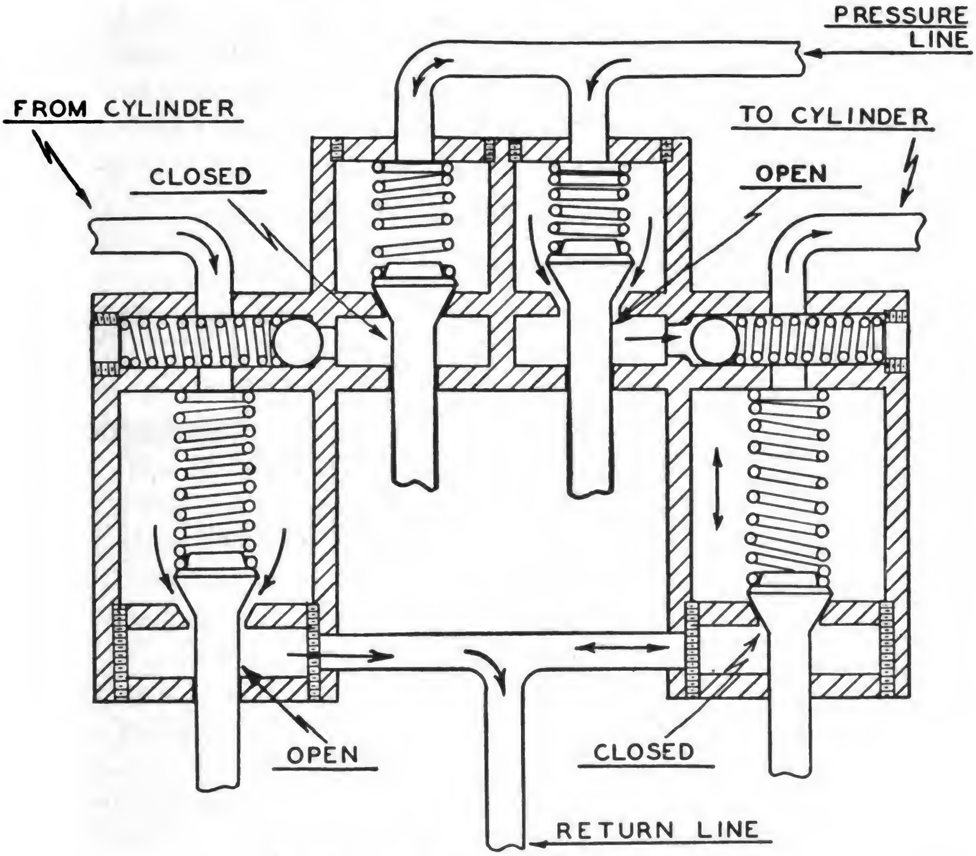


FIGURE 21.—Poppet type selector valve.

to stop the mechanism before it has reached the end of a stroke. This use of the valve is applicable to wing flap control. The setting is termed the "neutral" setting of the valve.

d. The piston type selector valve consists of a grooved piston within a cylinder. The piston is hollow part of its length. The hole in the piston provides a fluid passage to the outport of the valve. The inport of the valve is midway of the cylinder and the outport is in one end. The two ports leading to the actuating cylinder are on the side of the cylinder opposite the inport. By moving the piston back and forth in the cylinder, the desired port alinement is obtained. When none of the ports aline, the valve setting is neutral.

e. The poppet type selector valve consists of a series of spring loaded cone seat valves. The valves are actuated by cams. The cams are so disposed on the camshaft that rotation of the shaft opens the proper combination of valves to effect the desired control of flow through the valve assembly. A control handle fastened to the camshaft provides a means of rotating the shaft. Each selector valve has two inlet valves and two outlet (unloading) valves. When one

of the inlet valves is opened, a companion outlet valve opens. When the alternate inlet valve is opened, the other outlet valve opens. Thus, fluid flow is controlled and directed to the actuating cylinder. When all four valves are closed, the setting is neutral; and the control handle is in the neutral position.

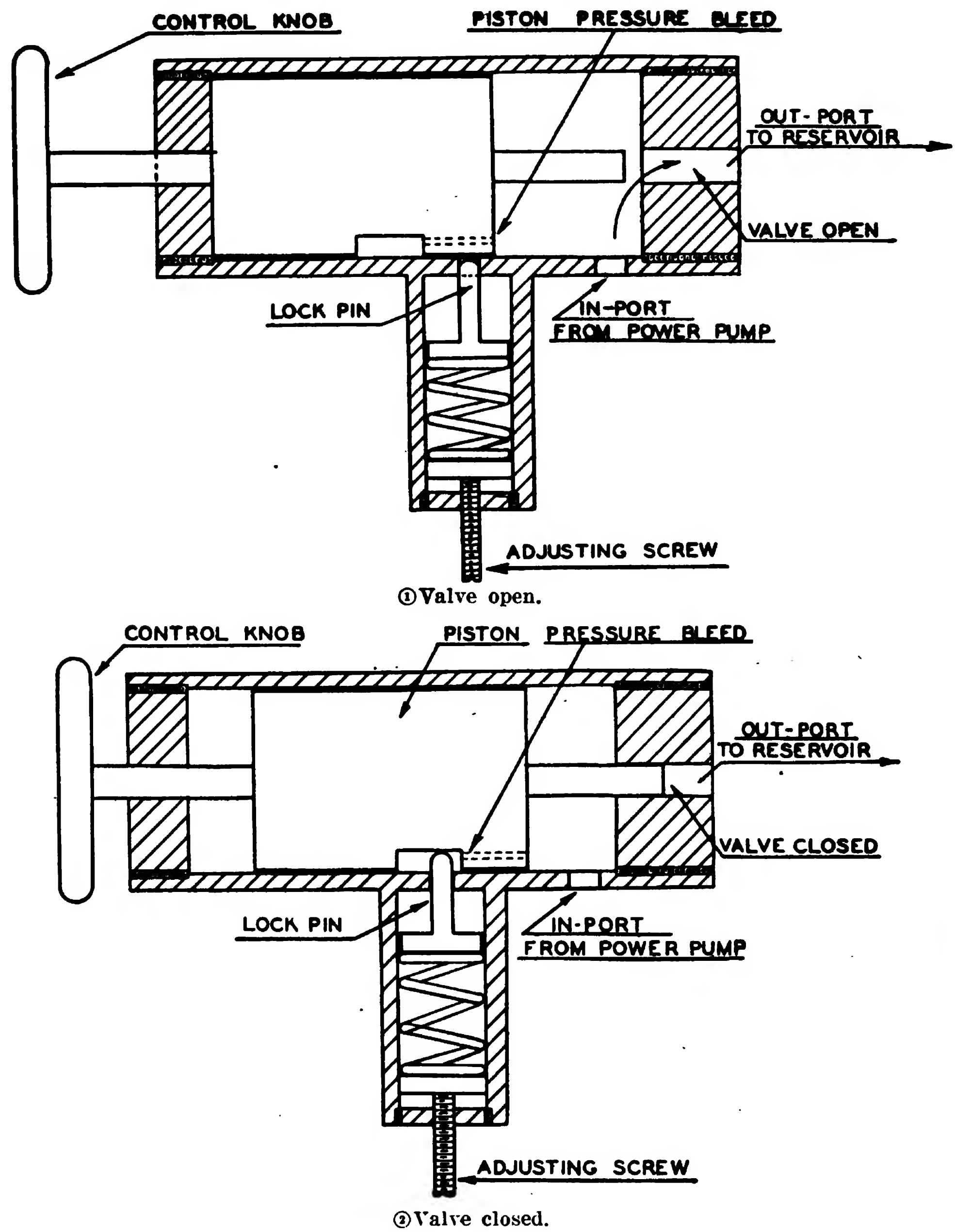


FIGURE 22.—Power control valve.

17. Power control valve.—*a.* A power control valve is essentially a hand shut-off valve with an automatic turn-on feature. It

permits the circulating of fluid from the power pump to the reservoir without imposing on the pump the burden of continuously developing the high pressures required to keep a relief valve open. In this respect the power control valve performs the same function in a system without a pressure tank that a pressure regulator does in a system that includes a pressure tank.

b. When pressure is not required in the hydraulic system, the output of the power pump is directed through the power control valve as illustrated in figure 22 and thence to the reservoir. When pressure is required in the system, the knob on the power control is pressed inward as shown in figure 22. This causes a piston to enter the outport of the valve and thus close the fluid passage through the unit. The output of the power pump is now directed into the system where pressure builds up to actuate the mechanism. When the mechanism has been moved to the limit of its stroke, excess pressure develops in the system and in the power control valve. This excess pressure lifts the spring loaded pin that locks the piston in the closed position. The pressure that lifts the pin also slides the piston out of the outport. This opens the passage in the power control valve and again permits the fluid to circulate freely to the reservoir. The pressure at which the valve releases is controlled by the tension of the coil spring surmounting the lock pin. An external adjustment is provided for the purpose of regulating the tension of the spring. When the valve releases, the control knob is returned to its original position. Power control valves are usually located in close proximity to the selector valve controls.

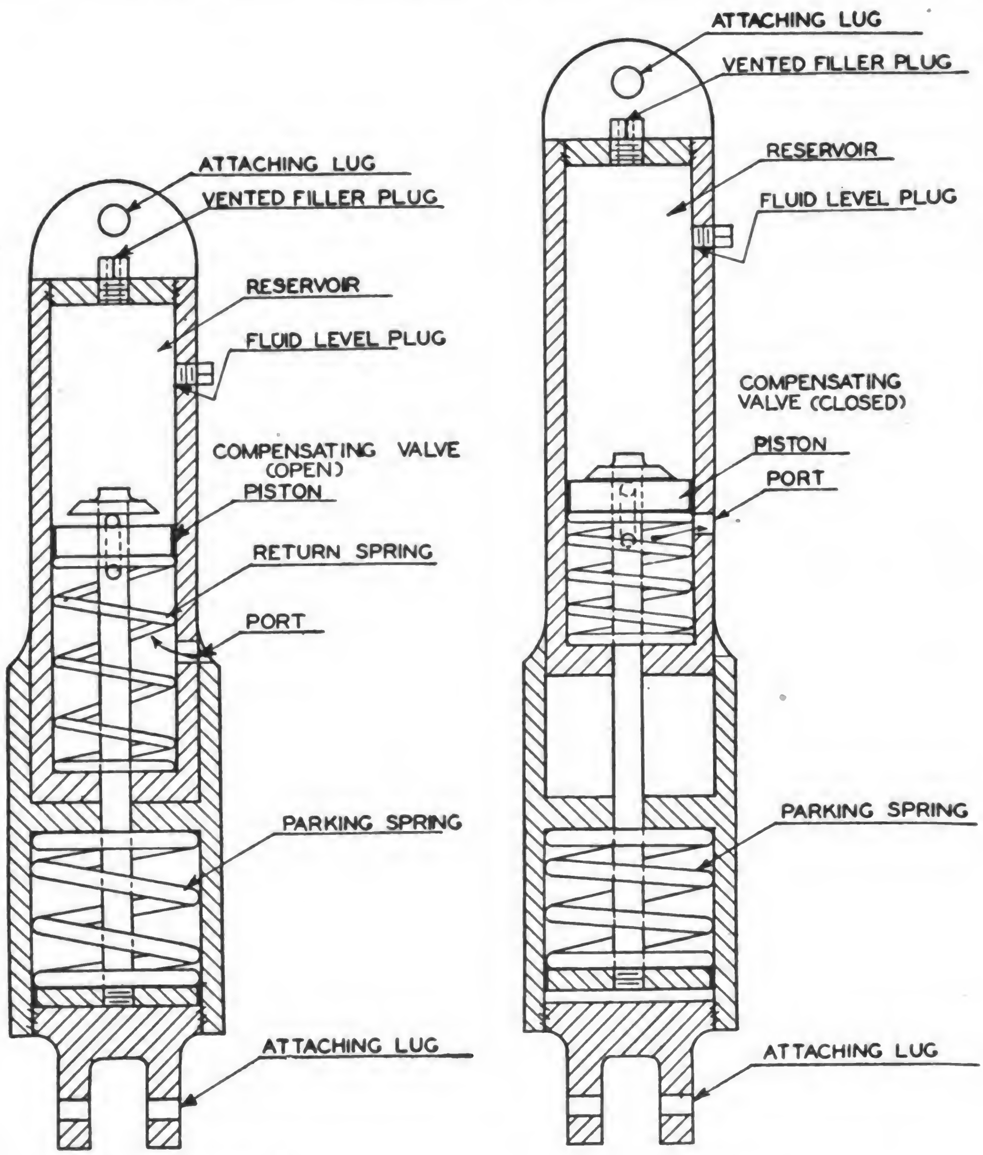
c. In case more than one power control unit is installed in an airplane, they are connected in series so that the manipulation of any one of them is equivalent to manipulating all of them in unison, that is, if the knob of any one of the power-control units is pushed inward, the circulation of fluid to the reservoir is shut off and pressure starts to build up in the hydraulic system.

18. Master cylinder.—*a.* The master cylinder (fig. 23) is the energizing unit of a hydraulic brake system; a system separate and apart from the general hydraulic system. There is one master cylinder for each wheel brake—one distinct hydraulic system for each brake assembly.

b. A master cylinder is a manually operated, single-action reciprocating piston pump. It is operated by a toe pedal mounted one on each of the two rudder pedals. Usually each master cylinder is fed from a reservoir integral in the unit. In some cases, however, the two cylinders are fed from a common reservoir or supply tank. In

any case, the reservoir is vented and the feed to the working chamber of the unit is by gravity.

c. When pressure is applied to the toe pedal, the piston is advanced within the cylinder. When pressure is released on the toe pedal, a



①Brake off. ②Brake on

FIGURE 23.—Master cylinder.

coil spring forces the piston back to its original position. On the down stroke of the toe pedal, fluid is forced out of the master cylinder through the fluid line and into the brake actuating cylinder. On the return stroke, the piston in the master cylinder sucks the charge of

fluid back out of the fluid line and the brake actuating cylinder. It is evident that the fluid in the hydraulic brake system does not circulate; it simply flows back and forth.

d. To preclude the possibility of the brakes being applied by pressure developed by temperature expansion, a compensating valve

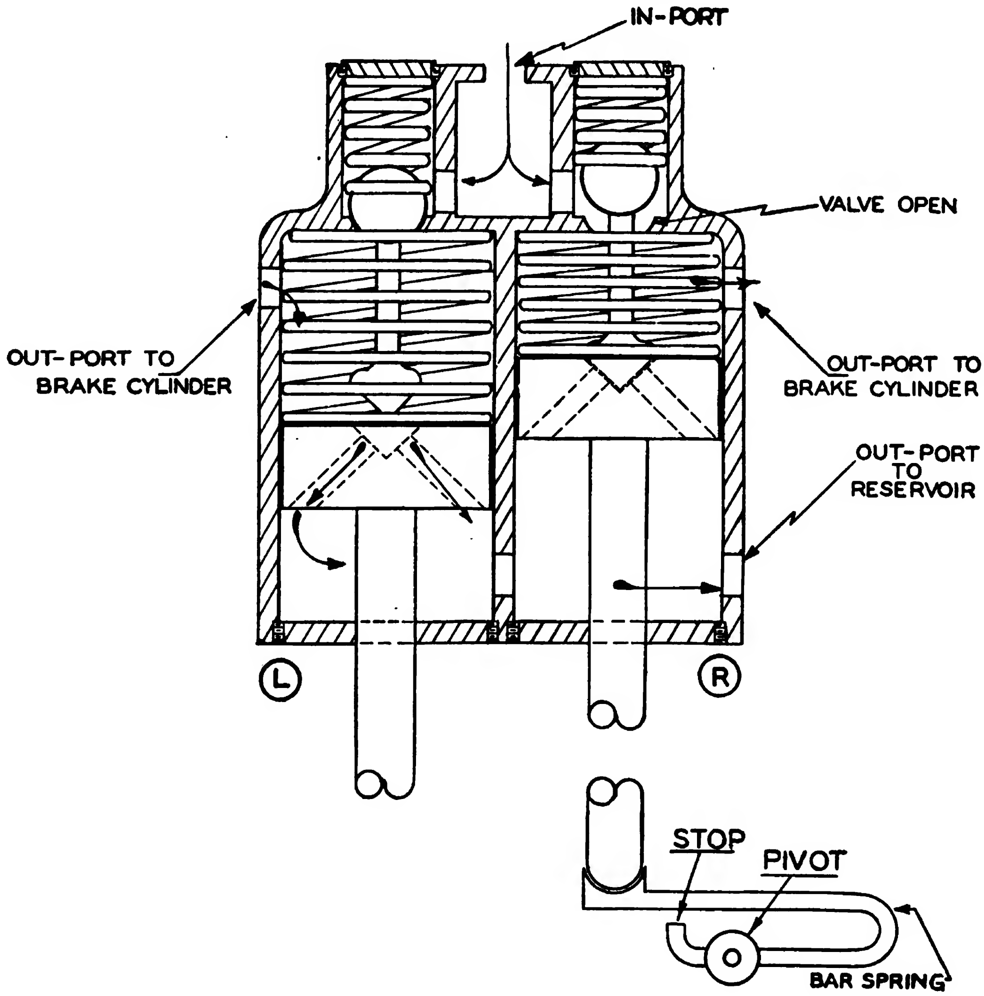


FIGURE 24.—Brake control valve.

is placed between the working chamber and the reservoir. This valve is open at all times when the brakes are "off." The valve is an adaptation of a flap valve and simply falls open. During application of the brakes, fluid pressure within the working chamber holds the valve closed. The resiliency of the coil spring absorbs the excess pressure caused by temperature expansion when the brakes are in the "on"

position. The spring also assures that the brakes remain "on" in case of fluid contraction caused by decrease of temperature.

e. To enable the brakes to be locked in the applied or "on" position, a mechanism called a parking brake is incorporated in the brake system. This is a manually operated latch by means of which the toe pedals are held in the depressed or "on" position. When the latch is released, the pedals return to the neutral or "off" position.

19. Brake control valve.—*a.* A brake control valve is used in place of a master cylinder to actuate the wheel brakes of the larger airplanes where high brake pressures are required. It is a device for metering fluid out of the pressure manifold of the hydraulic system at a pressure required to operate the brakes.

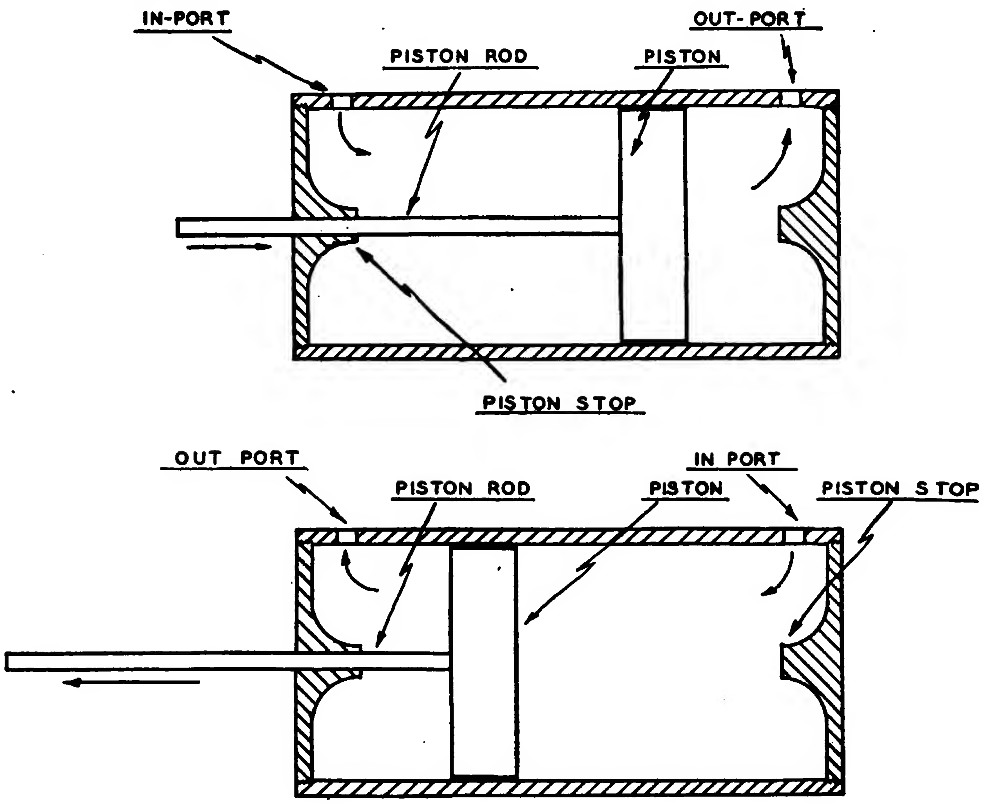


FIGURE 25.—Actuating cylinder.

b. When pressure is applied to the brake pedal, a piston and valve pin are pushed upward, as shown in R, figure 24. The valve pin unseats a spring loaded valve in the head of the unit. Fluid enters through the open valve and then flows through a port into the brake line. Fluid will flow into the brake line until the piston pressure and brake pressure are equal. The piston and pin will now be forced down, allowing the ball to seat and relieving the brake from further

increase in pressure. A bar spring in the brake control linkage will accommodate the downward movement of the piston for a given position of the brake pedal. When pressure is released on the brake pedal, the piston moves down, unseating the valve pin as in L, figure 24. As soon as the piston and valve pin are separated, two holes in the piston are uncovered, thus providing an outlet for the fluid to flow into the return manifold of the hydraulic system and relieve the brake pressure.

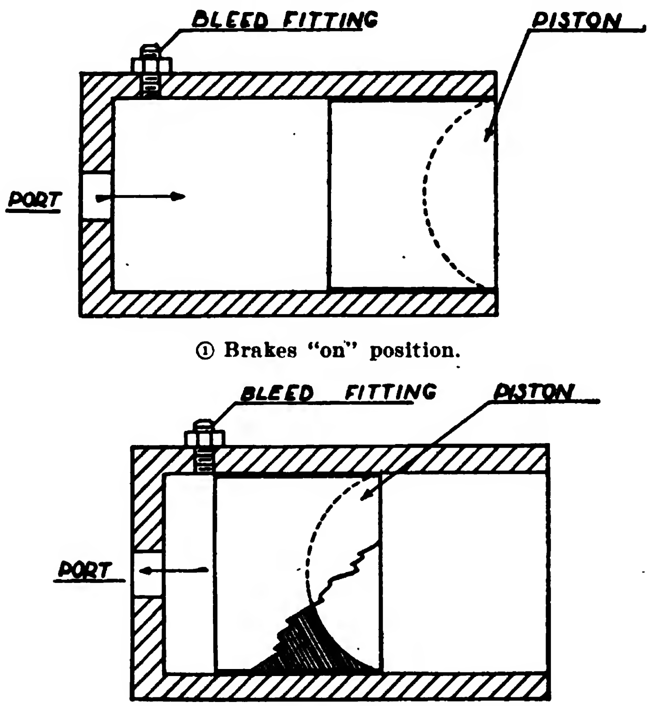
20. Actuating cylinder.—*a.* An actuating cylinder is the unit in the hydraulic system where fluid pressure is transposed into mechanical action.

b. An actuating cylinder (fig. 25) consists of a cylinder containing a piston, a piston rod, and piston-rod seals. The piston rod extends through one end of the cylinder. Two ports are located near the ends of the cylinder. Each port is alternately an inport and an outport, depending upon the setting of the control valve.

c. Upon fluid entering one of the ports, the piston is driven toward the opposite end of the cylinder. The piston rod transmits the motion of the piston, and the mechanism to which the piston rod is fastened is caused to move. The fluid ahead of the piston is pushed out of the cylinder and is returned to the reservoir by way of the control valve and return manifold. By changing the setting of the control valve, the direction of flow of the fluid from the control valve to the actuating cylinder is reversed and the direction of travel of the piston is thereby reversed. Upon completion of the reverse movement, the mechanism has been moved through one complete cycle, or two complete strokes.

d. Although the above describes a cycle of operation of actuating cylinders in general, the brake actuating cylinder (fig. 26) must be mentioned as an exception. In this case the cylinder has but one port. As fluid under pressure enters this port, the piston is pushed toward the opposite end of the cylinder. When the stroke has been completed and pressure released on the fluid, the return springs in the brake assembly push the piston back to its original position and force the fluid out of the cylinder and into the fluid line from whence it came.

21. Return manifold.—The return manifold (fig. 27) is, in general, that side of the hydraulic system which returns the fluid from



① Brakes "on" position.

② Brakes "off" position.

FIGURE 26.—Brake cylinder.

the actuating cylinders, the relief valves, and the power control valves to the reservoir. It parallels, in reverse, the service of the pressure manifold.

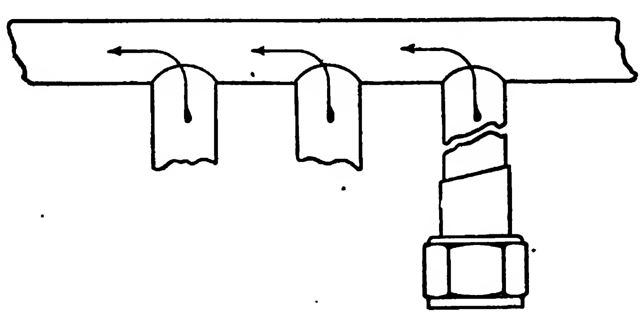
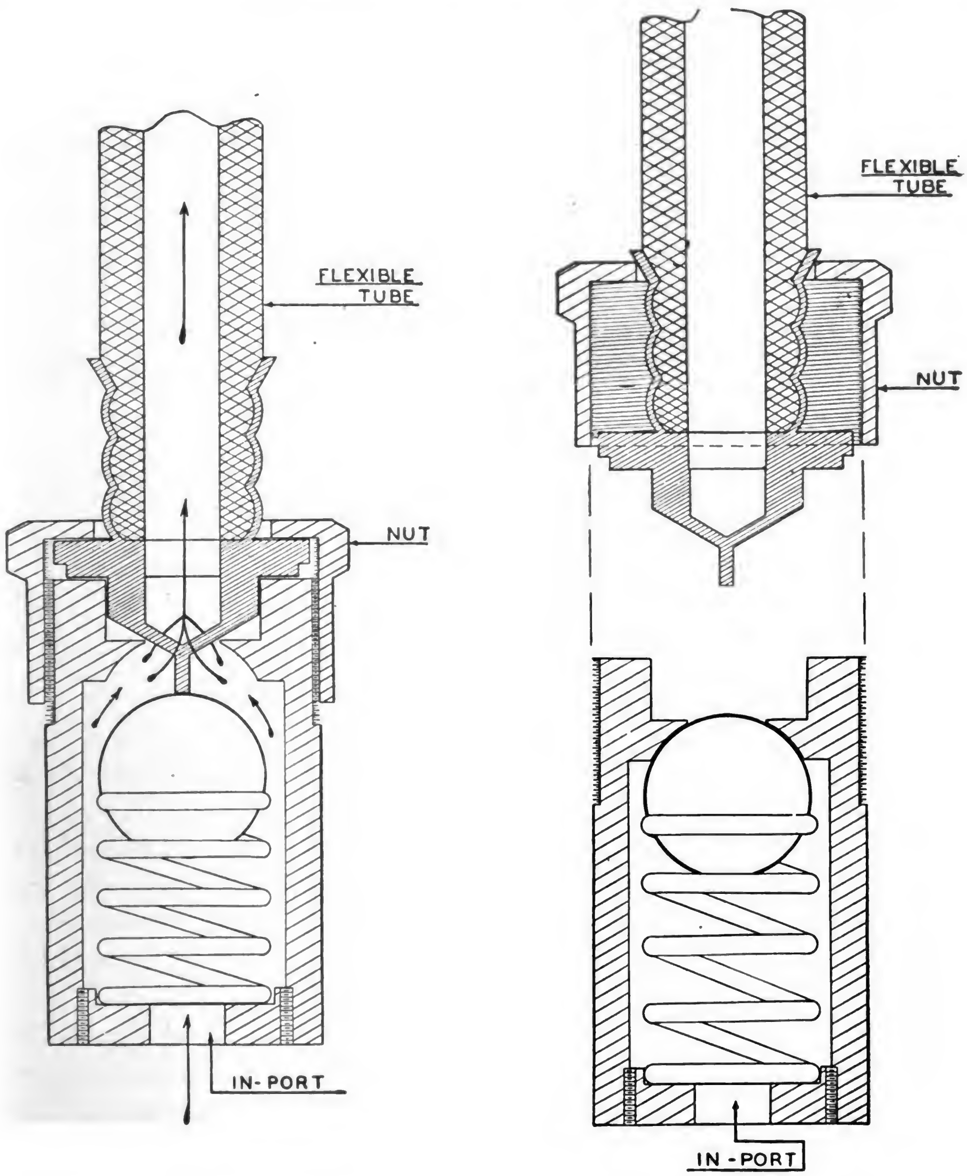


FIGURE 27.—Return manifold.

22. Line disconnect.—A line disconnect is a check valve installed in the end of a tube. When the tube is connected to another tube as shown in ①, figure 28, the check is held off its seat. The check valve is thus kept open as long as the two tubes are connected. When the two tubes are disconnected, as in ②, figure 28, the check

immediately falls into its seat and seals the tube in which it is installed. Line disconnects are generally used at the fire wall where connections are made from the engine assembly hydraulic system to



① Line connected. ② Line disconnected.

FIGURE 28.—Line disconnect valve.

the main hydraulic system. The use of these units obviates the necessity of draining or partially draining the hydraulic system to make an engine change.

23. Pressure gage snubber.—*a.* A pressure gage snubber is a device for damping the oscillations of the pressure gage indicator. The pressure impulses originating in the power pump and transmitted through the fluid to the pressure gage tend to oscillate the indicator. Although these oscillations are of fairly small amplitude, they are nevertheless jerky and disconcerting to the observer of the gage.

b. A snubber (fig. 29) is essentially an orifice with a plunger in it. The orifice is disposed vertically. The plunger in the orifice is free to bounce up and down. Due to the inertia of the plunger, the cadence imparted to it by the pressure impulses will not long synchronize with beat of the impulses themselves. The result is damped oscillations and a steady indicator. The snubber is mounted in the pressure line to the gage and it is usually placed close to the gage.

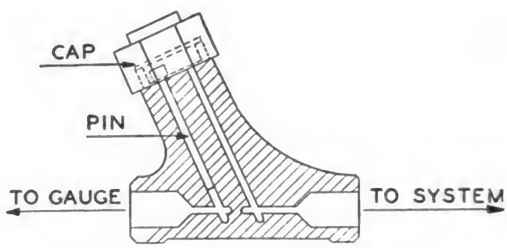


FIGURE 29.—Pressure gage snubber.

24. Bleed.—*a.* A bleed may not properly be termed a unit of hydraulic equipment but it is an important feature of certain hydraulic units.

b. The object of a bleed is to transfer pressure past the seal of a hydraulic unit. It constitutes a perpetual internal leak in the unit. The bleed permits of a slow and gradual equalizing of pressures on either side of the seal. It is essentially a device for normalizing pressures.

c. A bleed consists of an extremely small hole drilled in the unit in such a manner as to shunt fluid around the seal as shown in figure 18. In case a check or bypass check valve is installed in the pressure manifold, it is not uncommon to provide it with a bleed so that excessive pressures created by temperature expansion in the lower section of the manifold can reach the pressure tank or surge chamber, or other pressure absorbing device in the upper section of the manifold.

Section III

AIRPLANE HYDRAULIC SYSTEMS

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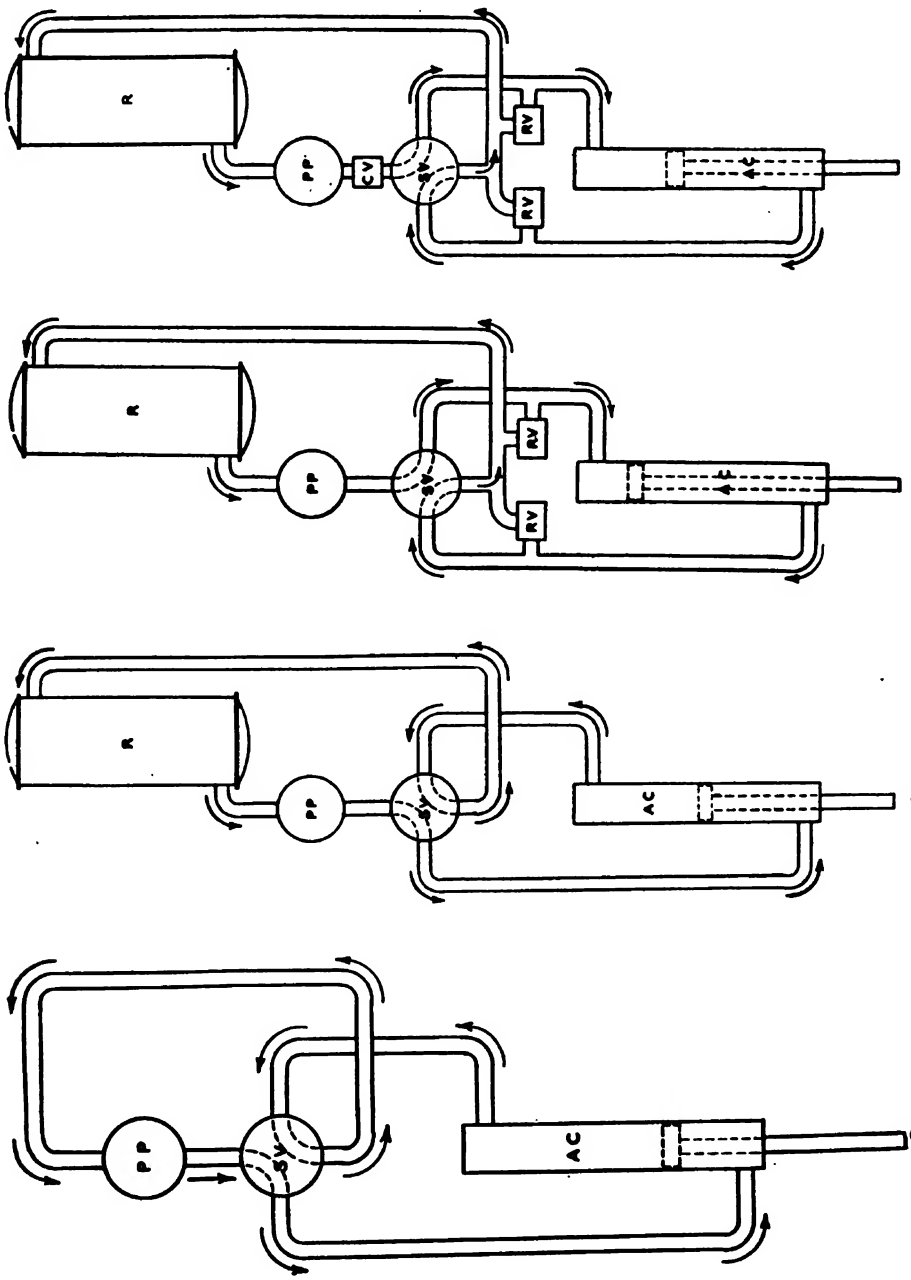
25. General.—A system wherein fluid is used to transmit a force to operate a mechanism is called a hydraulic system. A suitable pump may be used to develop the force. The force is transmitted through a column of fluid confined in pipes to a piston against which the force is directed. The piston is contained in a cylinder, and means is provided for preventing fluid from escaping past the piston. The piston rod is attached to some mechanism so that movement of the piston may operate the mechanism. The force applied to the piston, if of sufficient magnitude, will operate the mechanism. The fluid is forced into and out of the cylinder. The expelled fluid is returned to its original source or reservoir. The direction of flow to and from the cylinder, and consequently the direction of travel of the piston in the cylinder, are controlled by a manually operated valve. The fluid circulates throughout the system. Such are the elements of a hydraulic system of the type used in airplanes.

26. Elementary system.—*a*. An elementary hydraulic system is illustrated in figure 30 ①. This system is presented for the purpose of stressing certain inherent faults and is not intended to represent a hydraulic system suitable for installation in an airplane. The system shown is limited in application and is operative under certain conditions only. The restricted conditions under which such a system is operative preclude its use for practical purposes. The system is a sealed circuit, and, as such, a change of fluid volume will affect its successful operation. It is characteristic of fluids to expand with an increase of temperature and to contract with a decrease of temperature. Since it may be assumed that the system in this case was completely filled with fluid to start with, any tendency of the fluid to expand with an increase of temperature must result in an increase of fluid pressure. Although an increase of fluid pressure will not in itself render the system inoperative, it might, if excessive, rupture the lines. In the case of a decrease in temperature and in the case of fluid leakage, the resulting decrease in fluid volume will

starve the pump and decrease its efficiency. In case the decrease in fluid volume becomes excessive, the pump will perform spasmodically or may cease to pump entirely. To overcome the inherent weakness referred to, a fluid reservoir is incorporated in the system as shown



AC—Actuating cylinder. PP—Power pump. RV—Relief valve.
CV—Check valve. R—Reservoir. SV—Selector valve.

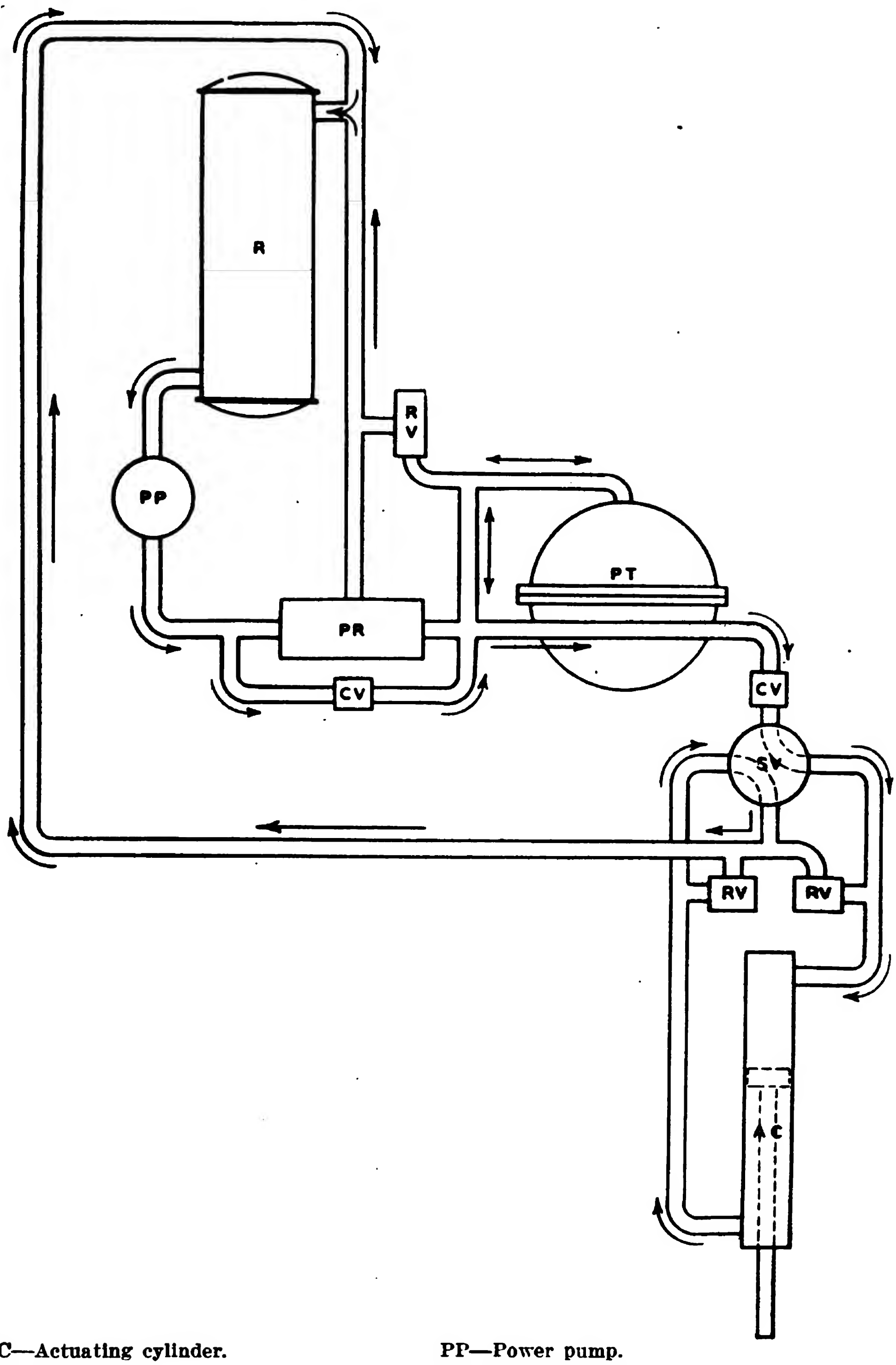
FIGURE 30.—Stages in development of simple hydraulic system.

in figure 31. This reservoir is vented to the air and is kept partially filled with fluid at all times. It serves as an expansion chamber as well as a source of supply of fluid to replace that lost through seepage and leakage.

b. The system including a reservoir as shown in figure 30 ② is limited in application for it can be employed only in conjunction with an intermittently operated pump. The inherent weakness in the system lies in the fact that the fluid delivered to the piston is in terms of the pump operation and not in terms of the piston requirements. In the case of fluid pumps installed in airplanes, the pump is often engine-driven and it is therefore in constant operation with the engine. In this case fluid is being constantly circulated whether it is required or not and some means must be provided for bypassing fluid in excess of that required to operate the piston. Provision must also be made for relieving the pressure when the piston reaches the end of its stroke and also when the piston requires a pressure to move it in excess of a safe operating pressure. Relief valves installed as shown in figure 30 ③ will bypass fluid back to the reservoir after a predetermined pressure for which the valves are set to open has been built up.

27. Improved system.—The system has now been improved to the point where it is practical and safe to operate; however, it lacks some of the refinements desirable in a system designed for use on airplanes. For the purpose for which hydraulic systems are used on airplanes, it is often desirable to hold the piston, and thereby the mechanism attached to the piston, fixed in position after the pump has been stopped. Such is accomplished by incorporating a check valve in the system as shown in figure 30 ④. This unit permits fluid to flow toward the actuating cylinder, but not away from it. A check valve installed between the pump and the control valve thus traps the pressure in the cylinder. To release the pressure, the control valve must be reversed.

28. Complete system.—*a.* The system has now been developed to the point where a limited amount of mechanism can be successfully operated. In the event that several groups of mechanism must be operated simultaneously, the fluid required to operate them may exceed the capacity of the pump to supply it. In such cases a pressure tank is resorted to as shown in figure 31. Such a pressure tank stores up energy and serves the same function in a hydraulic system as a storage battery does in an electrical system. As auxiliaries to a pressure tank, two additional units are required. These are a pressure regulator and a system relief valve. The pressure regulator is installed between the pump and the pressure tank and the relief valve between the pressure tank and the reservoir. This relief valve serves as a safety vent in case the pressure regulator fails to function properly and stop the flow to the pressure tank and



AC—Actuating cylinder.
CV—Check valve.
R—Reservoir.
RV—Relief valve.
PP—Power pump.
PT—Pressure tank.
PR—Pressure regulator.
SV—Selector valve.

FIGURE 31.—Complete hydraulic system with one actuating cylinder.

AC—Actuating cylinder.
AP—Automatic pilot.
BD—Bomb door hydraulic mechanism.
BCV—Brake control valve.
BPCV—Bypass check valve.
CV—Check valve.
FP—Flap gear hydraulic mechanism.
HP—Hand pump.
LDV—Line disconnect valve.
LG—Landing gear hydraulic mechanism.
MC—Master cylinder.
O—Orifice.
OCV—Orifice check valve.
PCV—Power control valve.
PR—Pressure regulator.
PT—Pressure tank.
PP—Power pump.
PGS—Pressure gage snubber.
PG—Pressure gage.
R—Reservoir.
RV—Relief valve.
SC—Surge chamber.
SV—Selector valve.
TG—Tail gear hydraulic mechanism.
TRV—Temperature expansion relief valve.

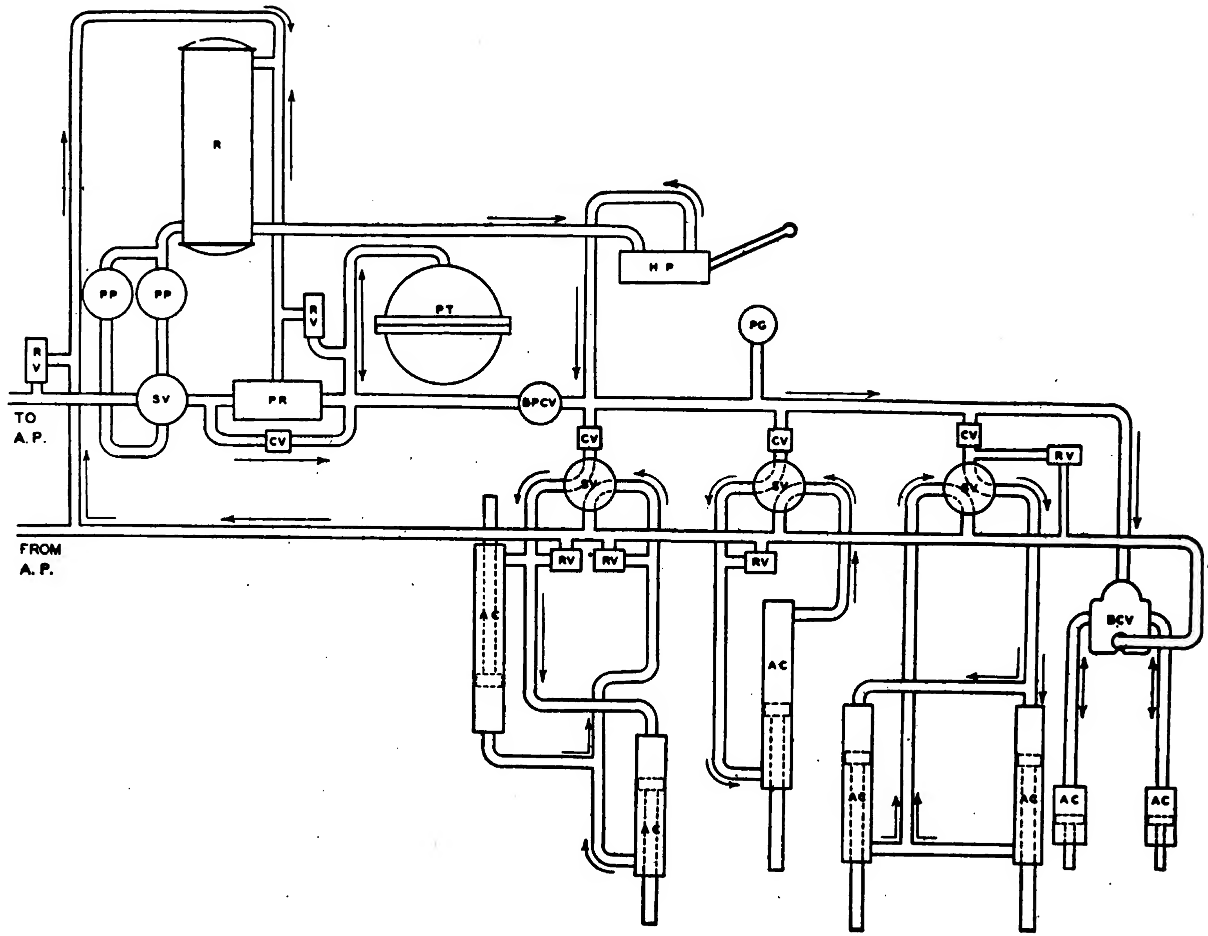


FIGURE 32.—Complete hydraulic system with multiple actuating cylinders.

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pressure manifold as it should. This relief valve is set to open at a pressure somewhat higher than the normal operating pressure required to operate the system.

b. A further refinement shown in figure 32 is the inclusion of a pressure gage installed in a convenient location in the pressure side of the system.

c. To provide an auxiliary source of power in case of failure of the engine-driven pump, a hand pump is essential in a hydraulic system intended for installation in an airplane. (See fig. 32.) This pump draws fluid directly from the reservoir and forces it into the pressure manifold. The hand pump must be resorted to in case the engine-driven pump is inactive and the pressure in the pressure tank is too low to operate the mechanism unaided. The hand pump may also be used to raise the pressure in the pressure tank. A bypass valve installed between the hand pump and the pressure tank will direct the output of the hand pump to the pressure tank when it is turned to tank position. The valve is normally left in the "system" setting.

d. Where an automatic pilot is hooked into a hydraulic system, it is desirable to use two engine-driven pumps, one pump serving the automatic pilot and the other the remaining mechanisms. A control valve installed in the pressure lines from the engine-driven pumps directs the flow two ways. Either pump may be made to serve either system by reversing the setting of the control valve. A relief valve installed in the automatic pilot pressure line will bypass fluid back into the general return line to the reservoir when the pressure exceeds the normal operating pressure required by the automatic pilot.

e. To facilitate the removal of the engine and engine mount, line disconnects are installed in the lines leading from the pumps. These units permit breaking the lines at these points without the loss of fluid or pressure.

29. A–17A airplane.—*a. General.*—There are two separate hydraulic systems in this airplane; one is used to operate the landing wheel brakes while the second operates the landing gear retracting mechanism and the landing flaps. The system is shown schematically in figure 33.

(1) A fluid reservoir is located on the left inside wall of the overturning structure. The filler cap is accessible from the outside.

(2) A power pump is mounted on the engine and driven by the left gun synchronizer shaft. It is driven at crankshaft speed.

(3) A hand pump is located at the left side of the front cockpit for convenient operation by the pilot, should the engine pump become inoperative.

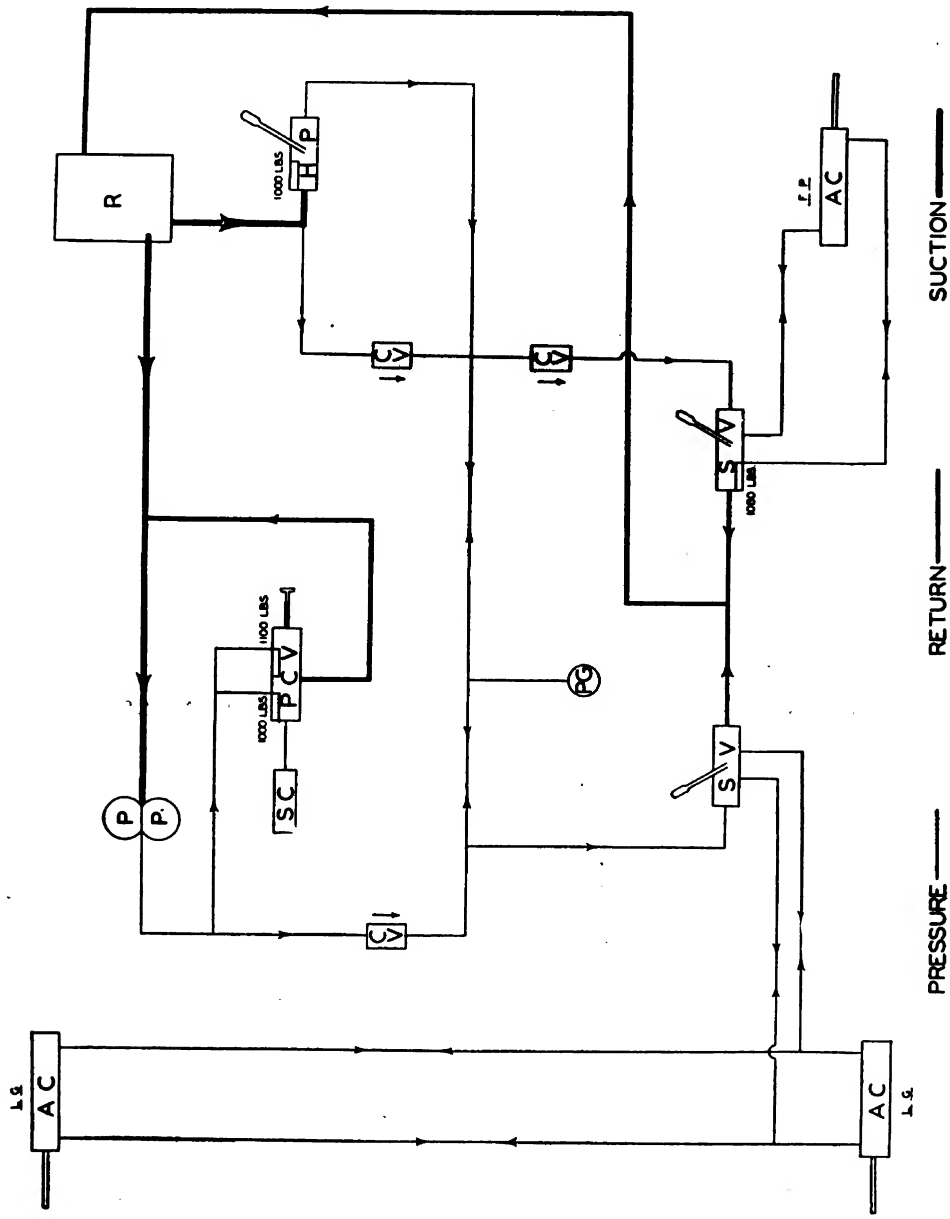

FIGURE 33.—A–17A hydraulic system.

(4) A power control valve, mounted on the upper left side of the fuselage just aft the fire wall, is connected to the engine pump. The control knob is located at the left of the center instrument panel. With this knob pushed forward, the fluid from the pump is diverted from the bypass to the system pressure lines. The power

control valve is set to open when the back pressure in these lines reaches approximately 950 pounds per square inch. The power control valve knob must always be back when valve is not in use.

(5) A surge cylinder, mounted on the rear side of the fire wall just above the center of the fuselage, is connected to the power-control valve. The purpose of this cylinder is to absorb momentary rises in pressure above 950 pounds and thus prevent disengaging the control valve before the landing gear is completely up.

(6) There are two selector valves, one for the landing gear hydraulic system and one for the wing flap hydraulic system. The control handles are located on the left side of the cockpit.

(7) A check valve in the pressure line just below the engine pump control valve prevents flow through the engine pump or power-control valve when the hand pump is used.

(8) A pressure gage is located beside the hand pump and is connected to the main pressure line.

(9) There are no special bleeder fittings on the landing gear or the flap operating cylinders as repeated operation of these systems forces any air up to the fluid reservoir in which it escapes from the system.

b. Brake system.—The brakes are operated by individual master cylinders which are connected by a linkage to the brake pedals. Each brake is operated independently of the other. Compensators, or springs, are included in the linkage between the brake pedals and the master cylinders. These springs, which are held in compression when the brakes are locked, obviate the possibility of the brakes becoming loose through contraction of the hydraulic fluid and prevent damage to the system in case of temperature expansion.

(1) To lock brakes, press both brake pedals, pull brake lock handle, and release pedals.

(2) To release brakes, press both brake pedals until brake lock snaps in, and release pedals. In case the brakes have been set and locked and a considerable rise in temperature should then occur, the fluid may expand enough to compress completely the compensator springs to such an extent that the brakes cannot be released by foot pressure on the pedals. If this condition should occur, the pressure in the system may be relieved by allowing some of the fluid to escape from the bleeder valve of each wheel.

c. Landing gear system.—Rotation of torque shafts retracts the landing gear by swinging the wheels and struts inboard and up into the center section of the wing. The torque shafts are rotated by individual hydraulic operating cylinders connected to arms on the

shafts, the pressure for which is furnished by an engine-driven pump or by an auxiliary hand pump at the left side of the pilot's seat. A selector valve directs the flow for extension or retraction of the landing gear. A control handle adjacent to the hand pump unlocks the latches and operates the selector valve located in the left landing gear nacelle.

(1) A vibrator warning device attached to the left rudder pedal operates when the throttle is closed and the landing gear is in any position except fully extended and locked. The vibrator may be made inoperative by pushing the small handle on the warning switch box at the left side of the pilot's cockpit. The vibrator automatically engages again when the throttle is reopened.

(2) To retract landing gear, have flap valve in the locked position. Push back the spring loaded lock which holds the selector valve handle in the down position, and pull up on the handle. Push forward on the power control valve knob and allow the knob to remain forward until both red capped, luminous, mechanical indicator arms protrude through the upper skin of the wing center section over the wheels and the pressure gage on the left-hand side of the cockpit remains constant at 950 pounds per square inch pressure or higher. Pull the knob completely back if it fails to kick out automatically. The indicators, easily visible from the cockpit, are a positive indication that the wheels are fully retracted.

(3) To extend landing gear, push down on the selector valve handle beside the hand pump, and push forward on the power control valve knob. Allow the knob to remain forward until the gear is completely extended and locked and the pressure gage remains constant at 950 pounds per square inch pressure or higher. When both wheels are locked in the extended position and the engine is idling, the vibrator will be inoperative. Furthermore, green capped luminous indicator arms will protrude through the upper skin of the wing center section.

(4) To retract or extend landing gear with the engine pump inoperative, move the selector valve handle beside the pump to the desired position (up for retraction, down for extension), and operate the hand pump until the landing gear is in the proper position as indicated by the signals. If the signals should not be in order, continue pumping until extreme stiffness is experienced. This will indicate that the gear is completely up or completely down.

d. Wing flap system.—An actuating cylinder, rigidly attached near the trailing edge of the wing center section, moves the flap control rods.

(1) A neutral position is provided in the wing flap selector valve in order that the flaps may be kept at any angle desired.

(2) To lower flaps, move the flap selector valve handle to the down position and push forward on the power control valve knob. Allow the knob to remain forward until the indicator shows that the flaps are lowered and the pressure gage remains constant at approximately 950 pounds per square inch. Then pull the knob completely back if it fails to kick out automatically.

(3) To raise flaps, move the flap selector valve handle to the up position and push forward on the power control valve knob. Allow the knob to remain forward until the indicator shows that the flaps are raised and the pressure gage remains constant at approximately 950 pounds per square inch. Then pull the knob completely back if it fails to kick out automatically. In flight, when the flaps are in the down position, if the selector valve handle is placed in the up position, the force of the air stream will close the flaps to approximately 15°.

(4) To raise or lower the flaps or landing gear without use of the engine pump, move selector valve to desired position and operate the hand pump.

e. Maintenance.—(1) To fill reservoir, have the landing gear extended and the flaps up to avoid subsequent overflow.

(2) To bleed the landing gear and wing flap systems, support the airplane so the wheels clear the ground. Fill the reservoir and alternately pump the landing gear and then the flaps completely up and down at least four times. There is no special bleeding arrangement in this hydraulic system as repeated operation of the system forces air up to the reservoir where it escapes from the system.

(3) To adjust relief valves—

(*a*) Have the landing gear completely extended. Keep the landing gear selector valve in the down position.

(*b*) On the top of the hand pump, back off the relief valve adjusting screw lock nut and turn the adjusting screw to the right until snug. This is to raise the release pressure of the hand pump temporarily until the flap selector relief valve is adjusted.

(*c*) Set the flap selector valve in the up position and operate the hand pump until the flaps are closed. Back off the adjusting screw lock nut on the flap selector relief valve. Operate the hand pump and turn the flap selector relief valve adjusting screw clockwise to raise the pressure and anticlockwise to reduce the pressure until the gage reading is 1,000 (+100−0). Tighten the lock nut and safety.

(*d*) Set the flap selector valve control handle in neutral position and adjust the hand pump relief valve until the gage reading is 1,000 (+50−0). Tighten the lock nut and safety.

(*e*) Start the engine and place the flap selector control handle in neutral position.

(*f*) On the automatic power control valve, back off the adjusting screw lock nut on the kick-out relief valve (the adjustment farthest from the wall of the fuselage) and turn the adjusting screw a few turns to the right or until snug. Care must be exercised that the adjusting screw is not turned in too far lest the composition seat of the valve piston be sheared off.

(*g*) Back off the adjusting screw lock nut of the system (over-load) relief valve (the adjustment nearest the wall of the fuselage) and with the engine throttle advanced to approximately 1,500 r. p. m., turn the adjusting screw until the gage reading is 1,100 (+50−0). Tighten the lock nut and safety.

(*h*) Back off the kick-out relief valve several turns. Place the flap selector control handle in the down position and with the engine throttle advanced to approximately 1,500 r. p. m., push the power control knob forward. Note the gage reading at which the control knob returns to its former aft position. Turn the adjusting screw to raise the kick-out pressure to 950 (+100−0). Make several tests by raising and lowering the flaps to verify the valve setting. When the adjustment is satisfactory, tighten the lock nut and safety.

30. BC-1 airplane.—*a. General.*—The BC-1 hydraulic system, shown schematically in figure 34, is employed for operation of the landing gear retracting mechanism and wing flaps. An engine-driven hydraulic pump is provided. A fluid reservoir is installed at the left side of the fuselage between the two cockpits. An emergency hydraulic hand pump and a pressure gage are installed on the left side of the front cockpit only. A power control knob is located at the left side of each cockpit. A separate hydraulic system is provided for operating the brakes.

(1) A compound landing gear and wing flap selector valve is located to the left of the pilot's seat. It has six ports: a pressure inport, a return outport, two ports to the wing flap, and two ports connected in parallel to the two landing gear retracting cylinders.

(2) A power control knob for controlling the operation of the flaps and landing gear by means of the engine-driven hydraulic pump is located forward of the flap and landing-gear control handles. An instruction plate for operation of the hydraulic system is mounted in the front cockpit forward of the control handles and adjacent to the

position indicators. After the control handles are set at the desired positions, the power control knob marked "PUSH" is pushed down. It is not necessary to hold the knob down after it has been pushed;

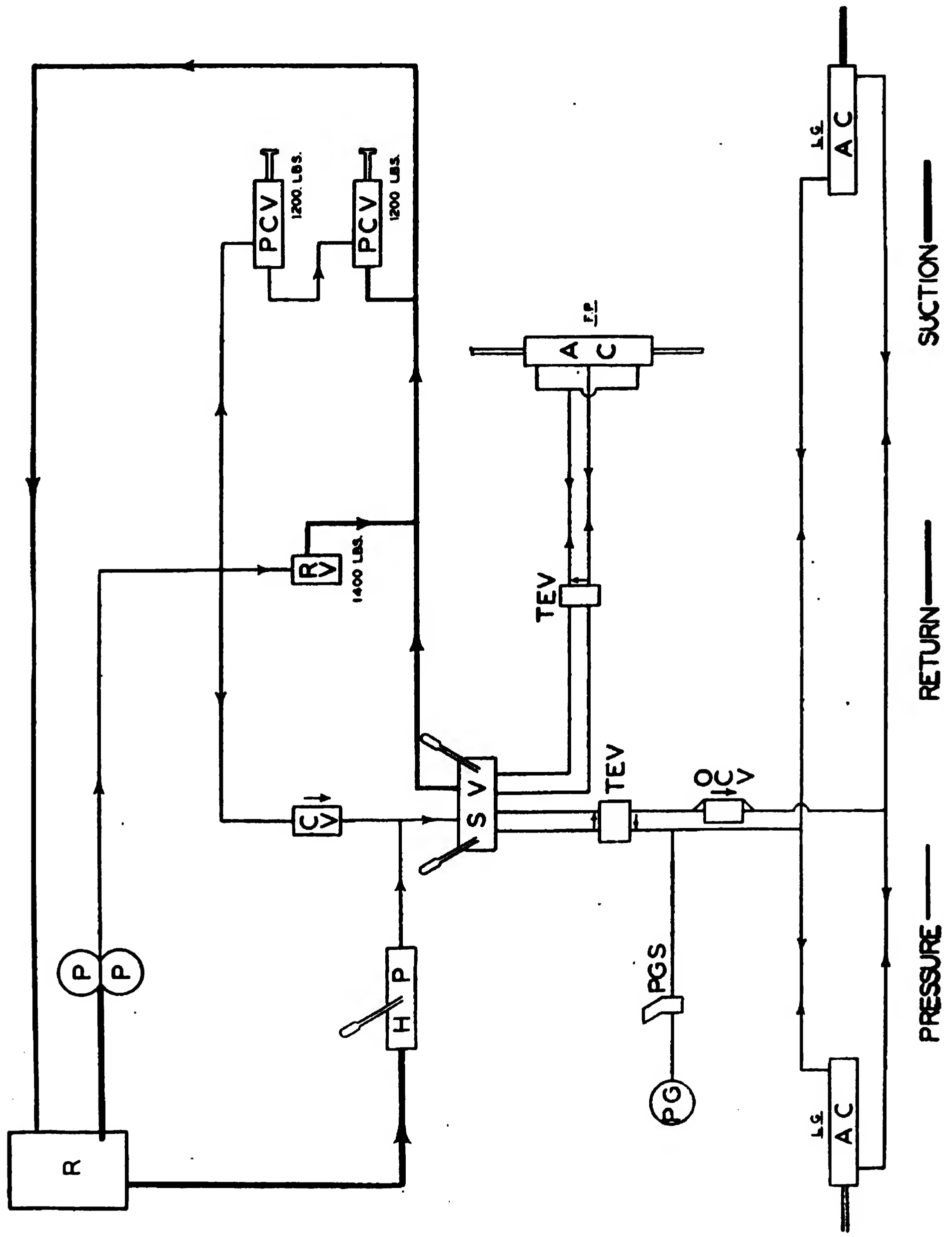

FIGURE 34.—BC-1 airplane hydraulic system.

however, sudden inertial loads due to bumpy air may cause the power control to disengage before a given action is completed, in which case it is necessary to push the knob down again. The power control automatically disengages when the operation is completed. If both power-

control knobs are depressed at the same time, they may both fail to disengage. In this event, both valves may be disengaged by firmly pushing down on the front power control knob for a few seconds and then quickly removing the hand. Should either valve individually fail to disengage, this method can also be employed on that valve. Manually pulling the push knob out does not disengage the valve since the knob is not directly attached to the valve mechanism.

(3) In the event of engine-driven hydraulic pump failure, the emergency hand pump located on the left side of the front cockpit may be used. In the event of both engine-driven pump and emergency hand pump failure in the hydraulic system, the landing gear will fall when the control handle is set for the down position. After the landing gear has reached the down position during this emergency operation without the use of either hydraulic pump, the latches may not engage until the wings of the airplane are waved to throw the gear into the locked position. The pressure gage will not show pressure; however, the landing may be completed if the vibrator warning device indicates a safe landing.

b. Brake system.—Brake pedals are incorporated in the rudder pedal assemblies. The brakes are hydraulically controlled and are actuated selectively from either front or rear cockpit. The parking brakes may be applied from the front cockpit only; however, they may be released from either cockpit by pressing the brake pedals. The parking brakes are set by means of the control knob located in the front cockpit below the instrument panel, which locks the brakes after they have been applied by the brake pedals.

c. Landing gear system.—The landing gear is pivoted at the upper portion of the oleo strut and is retracted inboard into the wing center section structure. The retraction is actuated by means of an engine-driven hydraulic pump, which may be operated from either front or rear cockpit; or a manually operated emergency hand pump, operated from the front cockpit only. Positive mechanical locks for both up and down positions are incorporated in the retracting mechanism.

(1) A selector valve control handle for the landing gear retracting mechanism is located on the left side of each cockpit. The control handle may be set for either "up" or "down," as desired. In the event that the landing gear is down and the latch pins are not in place, an unsafe landing condition is indicated by the vibrator warning device. It is then necessary to move aside the emergency plate, located on the forward portion of the landing gear control quadrant in the front cockpit only, and push the control handle through this extreme forward travel, which forces the down position latch pins in

place. This extra portion of the control handle travel is to be used in emergency only, and not for normal operation. The landing gear position indicator should not be used as a safe landing indicator, since it does not indicate the position of the down latch pins. The position indicator is located at the left side of the front cockpit.

(2) When the throttle is closed to a position below approximately 1,000 r. p. m., and the landing gear is in the up position, or the down position lock pins are not in place, an electrically controlled vibrator warning device is set into operation. A release switch is located on the pilot's switch box for rendering the vibrator inoperative when it is desired to close the throttle with the wheels in the up position. Opening throttle to approximately 1,200 r. p. m. automatically reinstates the vibrator.

d. Wing flap system.—A flap selector valve control handle is located on the left side of each cockpit, next to the landing gear control handle. The control handle may be set in either the up or down position. The lock position is used only when it is desired to stop the flaps at an intermediate position as indicated by the flap position indicator. If flap selector valve handle is left in lock position and temperature expansion occurs, it will cause leakage or damage as flap temperature expansion valve will only relieve with selector valve in up position. The flap position indicator is calibrated in degrees and is located in the front cockpit, just forward of the control handle.

e. Maintenance.—(1) With airplane in three-point position, fill reservoir with hydraulic fluid. The reservoir should be filled to overflowing, inasmuch as a visual inspection of the fluid level as seen in the filler neck is misleading.

(2) When the lines have been drained of fluid and the reservoir refilled, some difficulty may be experienced in getting the engine pump to prime. To check for satisfactory operation of the engine pump, operate the wing flap control handle and power control knob as required to lower and raise the flaps. If satisfactory operation of the flaps is obtained, the engine pump is functioning properly. If the flaps do not operate satisfactorily, proceed as follows:

(*a*) Stop engine and connect a globe valve to the pressure line T located on the front of the fire wall.

(*b*) Close the globe valve and start engine.

(*c*) Allow a small leakage of fluid from globe valve.

(*d*) Close globe valve and test for proper functioning of pump by operating flaps with power control.

(*e*) Allow leakage at globe valve until pump has primed itself.

(*f*) Stop engine, remove globe valve, and plug T fitting.

(3) To adjust system relief and pressure control valves, proceed as follows:

(*a*) From the plugged branch of the **T** fitting on the pressure line at the fire wall, run a line to a second **T** fitting.

(*b*) Connect a pressure gage to the second branch of the additional **T** fitting.

(*c*) Connect a globe valve to the third branch of the additional **T** fitting.

(*d*) Connect globe valve to plugged branch of suction line **T** at fire wall.

(*e*) The above piping simply connects the pressure line with the suction line through a globe valve and also incorporates a pressure gage into the system.

(*f*) Start engine and open globe valve.

(*g*) Back off pressure control adjusting screw lock nut and turn adjusting screw to the right several turns. This is to raise the kick-out pressure of the pressure control temporarily until the system relief valve is adjusted.

(*h*) Slowly close globe valve and note gage reading. Adjust system relief valve adjusting screw clockwise to increase the pressure and anticlockwise to reduce the pressure until the gage reading is 1,400. Tighten adjusting screw lock nut. Open globe valve to relieve the system of pressure.

(*i*) Back oil pressure control adjusting screw several turns and slowly close globe valve, thus building up pressure until pressure control disengages. Note gage reading at which pressure control kicks out.

(*j*) In the event that the control fails to disengage automatically, give knob a firm push and then release it.

(*k*) The globe valve should be closed slowly enough to require approximately ½ minute to build up the pressure from 0 to 1,200 pounds per square inch.

(*l*) After pressure control has disengaged, open globe valve again.

(*m*) Thus for every trial, open and close valve until the pressure control will consistently disengage at 1,200 pounds per square inch.

31. P–36A airplane.—*a. General.*—The P–36A hydraulic system, shown schematically in figure 35, consists of an electrically driven hydraulic pump for operating the retractable landing gear, tail wheel, and wing flaps, a hand pump for emergency operation, a toggle switch mounted on the left-hand side of the cockpit under the cabin sill for operating the electric pump, a reserve tank for

hydraulic fluid, and a hydraulic valve connected to two operating handles on the left-hand side on the floor of the cockpit.

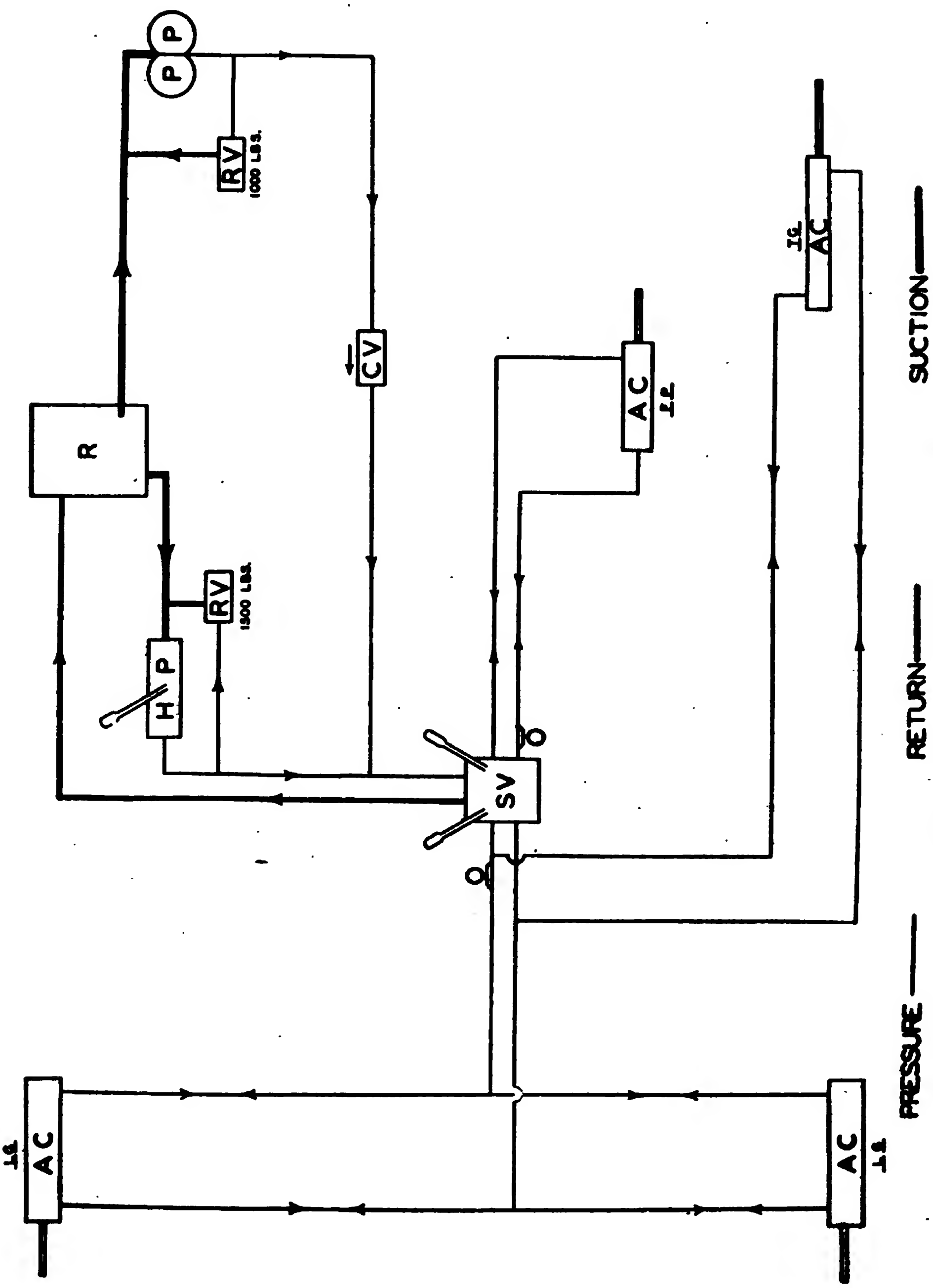

FIGURE 35.—P–36A airplane hydraulic system.

(1) An assembly consisting of a power pump and a 12-volt motor circulates the fluid. The pump is equipped with an integral relief valve adjusted to 1,000 pounds per square inch.

(2) The hand pump is a single-cylinder, reciprocating, double-acting pump. Each end of the cylinder is equipped with an intake check and a discharge check valve. A relief valve set at 1,500 pounds per square inch is integral with the hand pump. A special fitting is mounted on the hand pump to accommodate a pressure gage for checking relief valve pressures.

(3) The selector valve assembly consists of two operating handles connected to two camshafts on which the cams operate a series of poppet valves for the control of fluid flow.

(4) An orifice is installed in the landing gear hydraulic system to eliminate pressure differentials and consequent undesirable flow characteristics resulting from unequal piston areas and displacements in the landing gear and tail wheel retracting cylinders. This fitting is installed on the control valve in the **T** fitting for the return line from the landing gear when the landing gear is being lowered. If this fitting were not installed, the larger volume of return fluid flowing through one side of this **T** fitting from the landing gear cylinders would prevent the smaller volume of return fluid from the tail wheel cylinder from flowing into the other side of the **T**. The restriction in this fitting is $\frac{1}{16}$ inch in diameter and $\frac{1}{4}$ inch in length.

(5) An orifice is installed in the flap system in the control valve boss for the return line when the flaps are being raised. Due to the air loads on the flaps in the down position they will go up automatically as soon as the control valve is moved to the up position. The $\frac{3}{64}$-inch orifice controls the flow of fluid and regulates the rate at which the flaps move upward.

(6) A check valve is installed in the pressure line from the motor-driven pump in the fuselage. This valve is located on the left side of the airplane behind the overturning bulkhead. This check valve must have the arrow indicating the direction of flow pointing toward the control-valve assembly. Its purpose in the system is to prevent the electric pump being driven hydraulically when the hand pump is operated.

(7) In bleeding the hydraulic system, operate the landing gear twice by hand and three or four times by power and operate flaps several times, always taking care that the reserve tank is kept at least half full. Any air in the system is carried to the reserve tank and expelled. If the system still shows signs of air after the filling operation, it may be necessary to disconnect hydraulic lines at tail wheel retracting strut and bleed the system at this point. Do not replace filler cap until bleeding operation is completed.

b. Brake system.—The brakes are actuated by Warner hydraulic brake master cylinders mounted on and actuated by the rudder pedals in the cockpit. The parking brake lever located below the instrument board may be engaged when pedals are depressed and disengaged by depressing pedals.

c. Landing gear system.—The landing gear shock struts retract by rotating backward about a trunnion at the top of the strut. During retraction the strut is rotated 90° about its longitudinal axis by gears so that the wheel lies flush in the wing.

(1) The landing gear is locked in both the up and down position by hydraulically operated mechanical locks. A warning horn will operate when the throttle is closed except when the wheels are down and locked. A cam mounted on the throttle rod may be pulled out to disengage the horn operating switch temporarily. Engagement is automatic when throttle is next opened. Position indicator transmitters connected to the retracting mechanism are located in the wheel pockets. These transmitters are electrically connected to the position indicator on the instrument panel. An operation instruction plate is mounted in the cockpit.

(2) To retract the landing gear, depress button on landing gear control handle located at left side of pilot, move control handle to up position and operate the electrical pump with toggle switch located forward and just above the throttle quadrant. The switch must be held "on" during operation of the electric pump. An indicator on the instrument panel indicates position of the landing gear.

(3) To extend landing gear, place the control handle in the down position and operate the electric pump as before, holding the switch "on" a few seconds after the wheels are down to insure positive engagement of locks. Return the landing gear control handle to neutral except during operation of the mechanism. When the landing gear has been lowered, the control handle must not be raised beyond the neutral position due to possible loss of pressure with resultant disengagement of locks. Where any doubt exists as to pressure on the locks, the control handle will again be placed in the down position, the pump operated, and the handle returned to neutral position. The landing gear may also be operated by the hand-operated pump located on the right side of the cockpit.

(4) The tail wheel is fully retractable. The retracting strut has an integral, hydraulically operated, mechanical lock. This lock is not connected into the landing gear lock warning system. The tail wheel is locked in its down position by this mechanical lock, operated by hydraulic pressure, and is held in its up position by hydraulic

pressure alone. An indicator on the instrument panel indicates position of the tail wheel. The position indicator transmitter is mounted forward of and above the retracting strut.

(5) Before starting engine, taxiing, or landing, make sure that landing gear is locked down.

d. Wing flap system.—A single hydraulic actuating strut mounted on the airplane centerline bulkhead inside the trailing edge of the wing is used to control both flaps.

(1) To lower flaps, move the control handle (at left side of the pilot's seat) forward, and operate the electric pump with the toggle switch located forward and just above the throttle quadrant. The switch must be held "on" during operation of the electric pump. An indicator on the instrument panel indicates position of the flaps.

(2) To raise flaps, the control handle is set in the back position and the electric pump operated as before. Return the flap control handle to neutral position except during operation. The flaps may also be operated by the hand-operated pump located on the right side of the cockpit. In flight, flaps will go up automatically as soon as the control handle is moved to the back position, and caution should be exercised due to the resultant sudden loss of lift.

e. Maintenance.—(1) To fill and bleed the system, the airplane should be supported on jacks or cradles so that the landing gear and wing flaps can be operated. Fill reservoir with fluid. During filling operation, operate the landing gear twice by hand and three to four times by power and operate the flaps several times, always taking care that the reserve tank is kept at least half full. Any air in the system is carried to the reserve tank and expelled. If the system still shows signs of air after the filling operation, it may be necessary to disconnect hydraulic lines at tail wheel retracting strut and bleed the system at that point. Do not replace filler cap until filling operation is completed.

(2) To adjust system relief valve, install a pressure gage (range from 0 to 2,000 pounds) on adapter adjacent to the hand pump, operate hand pump and note gage reading. Regulate relief valve to bypass fluid at 1,500 pounds per square inch. Turn adjustment anticlockwise for pressure reduction. Upon completion of adjustment, remove pressure gage, install and safety pipe plug.

(3) To adjust power pump relief valve, install a pressure gage (range from 0 to 2,000 pounds) on adapter adjacent to the hand pump, operate the power pump and check to see that relief valve relieves at 1,000 pounds per square inch. If it is necessary to adjust the relief valve, loosen the locknut and turn the adjusting nut counter-

clockwise to increase pressure or clockwise to decrease pressure. Tighten the locknut and safety.

32. B-18A airplane.—*a. General.*—This system, less the automatic pilot, is shown schematically in figure 36. The complete system, including the automatic pilot, contains approximately 9 gallons of fluid. The fluid flows directly from a supply reservoir to two high pressure, engine-driven, oil pumps. A manually operated selector valve located on the inboard side of the pilot's seat support allows selection of the pump for supplying pressure to the main hydraulic system controlling the operation of the landing gear, wing flaps, bomb doors, and landing gear wheel brakes; the automatic pilot system being automatically served by the other pump. When the selector valve handle is in the forward (normal) position, the left pump supplies the hydraulic system and the right pump supplies the automatic pilot. When the selector control is in the aft position, the reverse is true. The fluid for the main hydraulic system passes to a pressure tank. From this tank it continues through the main system under a pressure of 600 to 800 pounds pressure.

(1) The operation of the landing gear, wing flaps, and bomb doors is controlled by individual four-way selector valves of the piston type. Movement of the piston connects the proper ports of the valves to allow operation of the various units of the system. The valves for the landing gear and wing flaps are located in an assembly in the floor between the pilot's and copilot's seats. The bomb door valve is located in the front gunner's compartment with remote control adjacent to the bomber. An emergency bomb release pull handle is located in the pilot's cockpit near the base of the control pedestal.

(2) An emergency hand pump installed on the hydraulic panel and located adjacent to the landing gear and wing flap four-way valves is so connected to the system that any hydraulic unit, including the brakes, may be operated by the hand pump. The hand pump may also be used to increase the pressure in the pressure tank when the bypass valve is changed from the normal system to tank position. The forward port of the hand pump connects to the pressure manifold, and the aft port connects to the reservoir.

(3) Two check valves are installed in the hydraulic hand pump system as the hand pump has but one integral check valve. When the pump handle is pushed forward, a check valve is unseated and fluid is forced to flow through the inner chambers and into the pressure manifold. When the pump is pulled aft, the check valve is seated and the fluid on the forward side of the piston head is forced out of the forward fitting into the pressure manifold, while

fluid is being sucked in through the aft side of the piston head through the aft port.

(4) The reservoir is made of aluminum alloy and is cylindrical in shape. The filling capacity is 2⅓ gallons and the total capacity

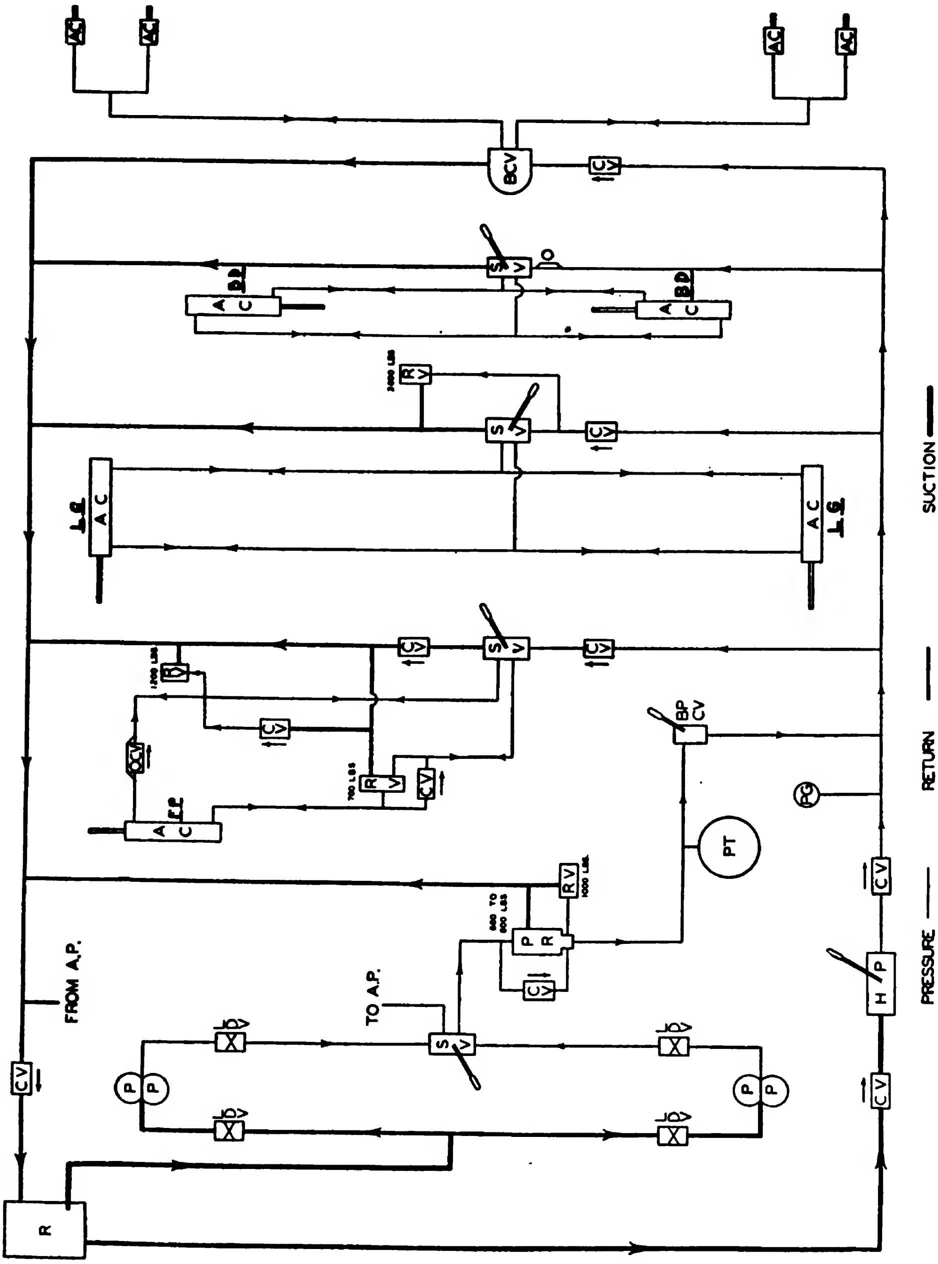

FIGURE 36.—B–18A airplane hydraulic system.

is 3½ gallons. A sight gage located beside the reservoir, when used in conjunction with instructions and filling marks on the sight gage panel, indicates the fluid level.

(5) The pressure tank consists essentially of two hemispheres of forged aluminum alloy and a synthetic rubber diaphragm which divides the tank into two chambers, one an air chamber and the other a fluid chamber.

(6) A pressure of 600 to 800 pounds per square inch is maintained in the pressure tank and the system by the pressure regulator. As pressure builds up, a plunger in the regulator moves inward, bearing on a coil spring at 600 pounds per square inch, the spring has been compressed to a point where an extension on the plunger bears on a ball which is held in place by the same fluid which moves the plunger. The parts are so proportioned that at 800 pounds per square inch the load on the plunger is exactly balanced by 200 pounds force on the ball and 600 pounds force on the spring. Any further increase in pressure causes the inward motion of the plunger to push the ball off its seat. Fluid from the pump rushes around the ball into the plunger chamber, flowing back to the reservoir by way of a port in the valve housing. The fluid from the pressure tank is prevented from returning to the reservoir by a check valve installed in a bypass line around the regulator. The plunger with an 800-pound load is now opposed only by a 600-pound resistance on the spring. Consequently, the ball will be held off its seat until the line pressure has dropped to 600 pounds per square inch.

(7) A system relief valve is connected to a port on the regulator and to the reservoir return line. Should the pressure regulator fail to operate and the pressure increase above 1,000 pounds per square inch, the relief valve will open and allow fluid to return to the reservoir. If it is impossible to raise the pressure in the pressure tank to 1,000 pounds per square inch by the use of the hydraulic hand pump after carefully checking the pressure regulator, pumps, and connecting line, this valve may be out of adjustment, allowing fluid to return to the reservoir before the proper release pressure is reached. This valve is located in the forward gunner's compartment and adjacent to the pressure regulator and the reservoir. To raise the pressure of the pressure tank by means of the hand pump, the bypass check valve must be set in tank position.

(8) The pressure gage indicates the pressure in the hydraulic system except that which is generated by temperature expansion in the landing gear, flap, and brake systems.

(9) The hand pump bypass or bypass check valve is connected in the main pressure line between the pressure tank and the valves controlling the main units of the system. It is mounted on the hydraulic panel. It is safetied in the system position with light soft wire, thus

connecting the hand pump directly with the system without going through the pressure tank. If it is necessary to increase pressure in the pressure tank with the hand pump, break safety wire and move valve control to tank position. A small bleed hole is located in the valve seat to relieve pressure in the bomb door operating system due to temperature expansion. Excessive pressures generated in this part of the system are thus able to get to the pressure tank where they are absorbed.

(10) A check valve is located adjacent to the reservoir in the fluid return line. This valve allows fluid to return to the reservoir but prevents it returning to the system through this line.

b. Brake system.—Hydraulic pressure is transmitted to the brakes through a power brake control valve, each wheel brake operating independently of the other. The valve housing encloses two piston chambers with pressure inlet and reservoir return in common, and separate ports to their respective brakes. Application of toe pressure to the rudder pedals causes the corresponding piston and valve operating pin to move up and raise a ball from its seat, connecting the brake and pressure lines. Fluid will flow into the brake line until the piston pressure and brake pressures are equal. At this point the piston and pin will be forced down, allowing the ball to seat and relieve the brake from further increase in pressure. There is no noticeable lag in this operation. When the toe pressure is released, the piston moves down, unseating the valve-operating pin. A fixed pin mounted through a slot in the piston prevents the operating pin from following the piston. As soon as the piston and pin are separated, two holes in the piston are uncovered allowing the fluid to flow out to the reservoir and relieve the brake pressure.

(1) A check valve is incorporated in the pressure supply line adjacent to the power brake control valve and allows fluid to pass into the control valve, but prevents its returning.

(2) To set brakes for parking, pull plunger type parking lock control located on the upper left corner of control pedestal base, depress rudder pedals until plunger moves out, remove pressure from pedals, and release plunger. To release brakes from parked condition, press on rudder pedals and spring will release the lock. The hydraulic system pressure gage must show at least 500 pounds per square inch pressure when the airplane is parked.

c. Landing-gear system.—The landing gear consists of two independent units; one mounted under each nacelle and so arranged that they may be folded up into the nacelles, leaving only the bottom of the wheels projecting.

(1) The landing gear selector valve is kept in either the up or down position except in case of a broken line when it is moved to a position midway.

(2) To retract landing gear, place the landing gear safety latch in latch raised position by pulling the control handle back until held by trip. A red warning light will go on as soon as the latch is raised. Move the landing gear selector valve control to up position and wheels will retract if hydraulic lines are under pressure. If for any reason the landing gear cannot be retracted with the engine pump, use the hand pump. After the wheels have come up into place, a hard stroke of the hand pump will insure that the axles are up against the rubber bumpers in the nacelles. Check the position of the wheels occasionally and if they are not up against the bumpers, pump them up with the hand pump.

(3) To extend landing gear, push the landing gear selector valve control to down position. This automatically places the safety latch in spring-loaded position. When the landing gear is down and latched, a green light will go on. Move the latch-control handle down against the floor, latch in positive-locked position. The clip on the floor should hold the latch handle down. The valve control should be left in down position at all times when the landing gear is extended. Approximately 35 seconds are needed to retract the landing gear and 30 seconds to extend it by using the hand pump.

(4) The landing gear indicating system consists of signal lights and a horn. The gear is down and locked only when the green light is on. When the red light is on, the gear is not down and locked. The horn will sound when either one of the throttles is closed and one or both wheels are not fully down and locked.

(5) A safety latch is mounted on the forward face of the front spar in each nacelle and is used to lock the landing gear in the extended position. The latch is controlled by a lever located forward of the landing gear selector valve. The valve handle and the latch lever are mechanically interconnected, making it necessary to manually raise the latch to unlocked position before operating the valve handle to retract the gear. Springs on the latch release and locking cables hold the latch lever in spring-loaded position. A clip on the fuselage structure should be used to hold the latch in positive-lock position. This clip should be used only when the landing gear is fully extended. The latch lever is held in unlocked position by the interconnecting mechanism. A trip lever for releasing the latch from unlocked position is located immediately aft of the latch lever. An aft thrust on this lever releases the latch.

(6) A check valve is located in the pressure line to the landing gear selector valve. This valve, by only allowing fluid to pass into the selector valve from the pressure line, permits the usage of other parts of the system without a drop in pressure in the landing-gear system.

(7) A relief valve is placed in the landing-gear system to compensate for temperature expansion of the fluid. It is connected to the pressure line between the check valve and the landing gear selector valve. When the landing gear is either up or down and temperature rises, causing an increase in volume of the fluid to such an extent as to cause approximately 3,600 pounds per square inch to build up in the pressure line, the relief valve will operate allowing excess fluid to return to the reservoir. This valve is located below and to the left of the landing gear selector valve.

d. Wing flap system.—The wing flaps are operated by a single actuating cylinder. A position indicator attached to the instrument panel in front of the pilot is connected by a flexible control to the hydraulic cylinder; any movement of the cylinder being shown on the indicator. The flaps may be placed in any desired position between full up and full down by moving the wing flap selector valve to the neutral position when the desired setting is reached. Approximately 7 seconds are needed to fully lower the flaps and 10 seconds to raise them from full down position with the engine-driven pump supplying the hydraulic pressure. Hand pump operation is much slower.

(1) The wing flap selector valve differs from the landing gear valve only in that it has three positions, namely; up, down, and neutral. The neutral position on the valve enables the pilot to lock the flaps in any desired position between the full up and full down. This is advantageous under certain take-off conditions.

(2) The down line of the wing flap system incorporates a relief valve which prevents the lowering of the flaps to the full down position if the airspeed is in excess of 112 m. p. h. However, this valve does not allow the flaps to rise when they are at full down position and the airspeed is increased above 112 m. p. h. If the flaps fail to lower fully, the relief valve is bypassing fluid because the airspeed is too high.

(3) A temperature expansion valve is connected between the flap up line and the return line to the reservoir. In case the temperature rises and causes the pressure in the line to increase above approximately 1,200 pounds per square inch the relief valve opens and allows the excess to return to the reservoir.

(4) A check valve is incorporated in the pressure line to the wing flap selector valve. Another check valve is connected into the wing flap system to allow fluid to flow from the down to the up side of the flap strut piston through the flap down relief valve.

(5) An orifice check valve is installed in the flap up pressure line to restrict the raising of the flaps.

e. Bomb door system.—There are two door operating cylinders connected by lever arms to the doors and when the pistons are extended by the pressure from the selector valve, the doors are closed. The bomb door selector valve can be operated by either the bomb door operating lever or the pilot's emergency release handle.

(1) The bomb door operating lever is located on the left side of the bomber's compartment. The pilot's emergency release handle is located at the base of the control pedestal within reach of the pilot and copilot. The pilot's emergency release handle is interconnected with the bomb door operating lever mechanism and the bomber's bomb control mechanism. In operating the pilot's emergency release handle the first part of the pull opens the bomb doors. When the doors open fully, a second pull on the handle drops all bombs in salvo. Instructions are contained on a plate located below the emergency release handle. The bomber's bomb control is located adjacent to the bomb door operating lever. This control has three positions: Lock, unlock, and salvo. The locking system between the bomb door operating lever and the bomber's bomb control is such that with the bomb door closed the bomber's bomb control cannot be moved from its locked position. Furthermore, when the bomber's bomb control is in either the unlock or salvo position the bomb doors cannot be closed. A bungee assembly helps to spring the doors to open position as soon as one of the three selector-valve controls is moved to open.

(2) There are no check nor relief valves in the bomb door operating system. However, a small bleed hole in the hydraulic hand pump bypass valve located between the pressure tank and the selector valve takes care of temperature expansion of the fluid. A special orifice fitting on the pressure port of the selector valve retards the operation of the bomb door system.

f. Maintenance.—(1) To bleed the system of air—

(*a*) Support the airplane on wing tripods.

(*b*) Operate the landing gear, wing flaps, and bomb door mechanisms through two or three complete cycles by means of the hand pump.

(2) To bleed the brakes—

(*a*) Set parking brakes.

(*b*) With at least 100 pounds per square inch pressure in the system, open bleeder port on each brake cylinder and allow about a pint of fluid to escape from each.

(3) To relieve the system of pressure—

(*a*) Insert safety pin in landing gear.

(*b*) Operate wing flaps up and down until the pressure gage reads zero.

(*c*) Place the landing gear selector-valve control in the up, then in the down position.

(4) To adjust the power brake control valve—

(*a*) Adjust low pressure screw:

1. Attach pressure gage to bleeder port on brake.

2. With at least 500 pounds pressure indicated on hydraulic pressure gage on instrument panel and no pressure on brake pedals, adjust low-pressure screw to give 10 to 15 pounds per square inch pressure at brakes.

3. Depress pedals halfway and release fully.

4. Back off screw until pressure drops to 5 pounds per square inch.

5. Back off $\frac{1}{4}$ turn more and lock. (Whenever low-pressure screw is adjusted, high-pressure screw must be readjusted).

(*b*) Adjust high-pressure screw:

1. Adjust screw to give approximately $\frac{1}{16}$-inch clearance between the high-pressure adjustment and the spring yoke.

2. With a minimum of 700 pounds pressure in system, push pedals down fully and note gage reading at brakes.

3. Release pedals and readjust screw (turn clockwise to increase pressure) and reapply brakes, until pressure of 600 (+50–0) pounds per square inch pressure is obtained. Do not turn high-pressure screw under load.

(5) To adjust landing-gear temperature-expansion relief valve, vary the number of washers between the heavy steel washer and the spring in valve body. Adjust to 3,600 pounds per square inch.

(6) To adjust wing-flap down-line relief valve, back off locknut and turn adjusting screw in end of valve clockwise to increase pressure. Adjust to 700 (+20–10) pounds per square inch.

(7) To adjust wing-flap temperature-expansion and system-relief valves, remove cap and screw guide clockwise to increase pressure.

Adjust flap relief valve to 1,200 (+50-0) pounds per square inch and system relief valve to 1,000 (+50-0) pounds per square inch.

(8) To adjust pressure regulator valve, disassemble and grind off spring to reduce pressure, or add washers under end of spring to increase pressure. If spring is ground, remove sharp edges and slivers. Adjust to 800 (+50-0) pounds per square inch.

(9) To clean the filter screen in the bottom of oil supply reservoir—

(*a*) Drain reservoir by removing plug in T connected to bottom cover.

(*b*) Remove eight bolts holding bottom cover to body.

(*c*) Remove lines attached to bottom cover.

(*d*) Remove filter screen and clean thoroughly with a stiff wire brush.

When replacing cover on reservoir, inspect vellumoid gaskets for condition and replace if necessary.

SECTION IV

INSPECTION OF HYDRAULIC SYSTEMS

	Paragraph
Operation check	33
Adjusting valves	34
Inspecting lines	35
Fluid supply	36

33. Operation check.—*a*. Operate each hydraulically operated mechanism through two or more complete cycles. In the case of the landing gear, make certain that the airplane is properly supported. Perform complete operation checks with the hand pump and also with the power pump. In case it is not convenient or safe to operate the engine driven pump, use an auxiliary source of power such as a hydraulic test stand. Use the pressure line and return line tap-ins, where such are provided; otherwise, break connections in the pressure side and in the return side of the hydraulic system and connect corresponding lines from the test stand. Observe the fluid pressure gage and compare the operating pressures attained with the operating pressures specified. Also compare the time required to operate the mechanism with the time specified as normal. Note whether the time required to operate the mechanism decreases with successive operations, indicating that air is being worked out of the system. Note whether a spongy reaction is experienced in operating the hand pump, indicating air in the system. Note if the hand pump operates with excessive ease, indicating an internal leak in the pump. Note whether the pressure attained with the power pump fluctuates, indicating an

inadequate fluid supply to the pump, or an excessive amount of air in the system. Note whether the mechanism operates with a jerky motion, indicating binding or fouling. Check the position indicators against the positions of the mechanism through a complete cycle of operation. Observe that the signal light and warning signal go on and off at precisely the proper time.

b. Operate the mechanism so as to leave a load on the actuating cylinders. With the pump inactive, note whether the mechanism creeps, e. g., whether the landing gear extends, the flaps lower, the bomb doors open, etc., indicating an internal leak in the cylinder or an internal leak in one of the valves in that section of the system.

c. Build up pressure in the pressure tank by means of either the power pump or the hand pump. With the pump inoperative, operate the mechanism so as to use up the stored pressure. Observe the pressure decrease as indicated on the pressure gage, until it suddenly drops to zero. The pressure indicated on the gage, just before the sudden drop to zero, is the air pressure in the pressure tank. In case this pressure is less than that recommended, it indicates an air leak in the pressure tank. An external leak can be detected by applying soapy water about the air valve and seam of the tank. An internal leak may be detected by noting fluid emerge from the air valve when the valve core is depressed, also by the complete and sudden depletion of pressure in the system upon any attempt to operate the mechanism with the pump inactive. In the case of systems employing power control valves, an air leak in the pressure tank will cause the power control valve to kick out prematurely and erratically as sudden pressure loads are imposed upon it.

d. Apply pressure to the brake pedals and if a spongy reaction is obtained, bleed the brake actuating cylinder. Use a rubber tube, one end of which is slipped over the bleeder fitting and the other end immersed in hydraulic fluid contained in a glass receptacle. Open the bleeder valve by turning the valve one turn to the left, and operate the brake pedal. Constantly replenish the fluid supply in the master cylinder reservoir. Pass approximately 1 pint of fluid through each brake system, or until air bubbles cease to come from the bleeder tube. Make certain that the rubber tube is tight about the bleeder valve, otherwise air will enter at this point and follow the fluid into the receptacle and give the impression that air is coming from the actuating cylinder. After bleeding, close the bleeder valve and recap it, then drain the reservoir to the proper level. In case the brake reaction is firm but the pedal creeps under applied pressure, an internal leak in the master cylinder is indicated. Either the transfer valve is par-

tially open and requires tightening, or the compensating valve is being held open by grit. In the latter case, the master cylinder must be disassembled and cleaned. In case the parking brakes jump to the off position from the parked condition, it is a further indication of an internal leak in the master cylinder or an external leak in the system.

34. Adjusting valves.—*a*. In adjusting relief valves, adjust but one valve at a time. Back out the adjusting screw of the valve to be adjusted, and screw in the adjusting screws of all other relief valves in the series. Start with the valve having the highest kick-out pressure and progress in descending order to the valve having the lowest kick-out pressure. In case a power-control valve is in the series, it must also be locked or held closed, and it should be adjusted last. Operate the mechanism and, with pressure applied against it, note the pressure at which the relief valve kicks out. Screw in the adjusting screw of the relief valve until the pressure indicated on the pressure gage is that required. Take several readings and consider the average as the setting of the valve. Back out the adjusting screw of the next valve to be adjusted and again apply pressure to the system and repeat the adjusting procedure. Screw in the adjusting screw until the desired kick-out pressure is obtained.

b. It must be realized that a check valve is usually placed between the hand pump outlet line and the system-relief and power-control valves; therefore, these valves cannot be checked nor adjusted with pressure furnished by the hand pump. Either the engine-driven pump must be used or else an external source of power must be resorted to.

35. Inspecting lines.—*a*. Shake fluid lines to detect loose anchorage. Investigate polished areas and worn spots to determine whether the lines have shifted or whether they have been fouled by moving parts of the airplane. Replace all lines that are deformed, dented, or kinked. Note whether flexible lines are held clear during operation of the mechanism. Squeeze flexible lines with the forefinger and thumb at points of suspicion to detect soft spots and deterioration. Keep flexible lines free of oil and grease at all times. Remove oil and grease with a cloth dampened with denatured alcohol.

b. Trace all fluid leaks to their source. Clean the equipment in the vicinity of the leak with denatured alcohol. If the tube leaks, replace it. If the leak is at a connection, tighten the connection. If this does not stop the leak, break the connection and inspect the tube flare for cracks, especially at the base of the flare. Inspect the fittings for defects. Replace defective fittings. Inspect the cone seats for burs, scratches, and imbedded grit. In making a connec-

tion it is permissible to use thread compound on the male threads only. The connection should be adjusted snug, but should not be forced excessively. A turning moment of not to exceed 100 inch-pounds applied to the nut of a ⅜-inch tube fitting should seal the connection. A turning moment of not to exceed 180 inch-pounds may be applied to ½-inch tube fittings.

36. Fluid supply.—*a.* Check fluid level and replenish with fluid of the specified type and grade. Make certain that the reservoir is serviced to the proper level. Make certain that the reservoir vent is not plugged. Attach a rubber tube to the end of the vent line and, with the filler cap loosened, suck on the tube. Open the sediment trap and remove the accumulated sediment. Clean the filter screen by rinsing it in alcohol and brushing it with a stiff brush.

b. The following fluids are used for servicing hydraulic equipment:

(1) Hydraulic fluid is used for hydraulic brakes, retracting mechanisms, and shock absorbers, except those listed in (2) and (3) below. This fluid is supplied in three grades, namely: light, medium, and heavy. The grades of fluid to be used for various temperature ranges are shown in (*a*) and (*b*) below:

(*a*) *Hydraulic brakes and retracting mechanism.*

Grade	Ground temperature—Average
B (medium)	+10° F. and above.
C (light)	+20° F. and below.

NOTE.—In case excessive leakage is encountered when using grade B fluid in hot weather, grade A (heavy) may be substituted.

(*b*) *Hydraulic shock absorbers.*

Grade	Ground temperature—Average
A (heavy)	+50° F. and above.
B (medium)	+10° F. to +60° F.
C (light)	+20° F. and below.

(2) Hydraulic fluid (Edgewater ring) is used in all shock absorbers employing Edgewater ring springs. Colloidal graphite has been added, and the fluid must be thoroughly stirred immediately before use. Only one grade of fluid is used for all temperatures.

(3) Aircraft hydraulic mechanism lubricating oil is used in automatic pilot systems, and hydraulic systems having a common reservoir supplying both the automatic pilot and other hydraulic equipment. No other hydraulic fluid may be used in lieu of this oil.

c. The temperature ranges given above show the desirable ranges of operation. Changes of fluid are not required for temporary

changes in temperature due to unseasonal fluctuation, occasional altitude flight, or temporary change of station.

d. At airplane overhaul all hydraulic equipment is disassembled, thoroughly cleaned, and refilled with new fluid.

e. (1) Except as noted in (2) below, hydraulic equipment is cleaned with denatured alcohol or butyl alcohol. Solvents other than these alcohols do not mix well with castor oil fluids and may cause deterioration of packings.

(2) An exception to the foregoing is made in the case of hydraulic systems that are serviced with lubricating oil. These are cleaned with kerosene, or naphtha, as some of the internal parts of the automatic pilot are made of materials upon which alcohols have a deteriorating effect.

f. Every precaution must be observed in handling hydraulic fluid to prevent its contamination. The storage containers must be kept sealed. All handling equipment must be kept clean and should be used for handling hydraulic fluid only. Do not expose hydraulic fluid to the air for periods in excess of those absolutely necessary. The fluid will absorb dust and grit from the air, and in certain localities this becomes a serious menace. Fluid that has been exposed to dust contamination should be filtered before using. Fluid that has been used should also be filtered before re-use. Filtering will remove the sludge from used fluid, as well as all metal flakes and grit.

g. The simplest equipment for filtering hydraulic fluid consists of a ribbed glass or metal funnel of approximately 1-gallon capacity, a sheet of standard commercial filter paper, and a container to support the funnel and contain the filtered fluid. The filter paper is folded into a funnel shape and placed in the funnel. The fluid passes through the filter slowly and should be protected from contamination by dust particles in the air. A cloth dampened in hydraulic fluid placed over the open end of the funnel will serve to protect the fluid during the filtering operation. The filtered fluid should be placed in clean containers properly marked to identify the contents and should be kept sealed until required for use.

Section V

GASES

	Paragraph
General	37
Properties	38
Storage	39

37. General.—*a.* The properties and basic principles of fluids considered in the preceding study of aircraft hydraulic systems apply

only to fluids in a liquid state. Miscellaneous aircraft equipment, however, involves fluids in a gaseous state and a study of this equipment necessitates some discussion of a few of the general properties and principles of gases and vapors.

b. The particular properties of each of the gases and vapors used in miscellaneous equipment will also be considered in this section.

38. Properties.—*a.* While liquids are considered practically incompressible (sec. I), fluids in a gaseous state, due to the freedom of their molecules, are very easily compressed or expanded. A consideration of this property presents the following three factors: pressure, temperature, and volume. The relationship of these three factors when applied to a gas is governed by the general law of gases.

b. This law states—

(1) That for a given mass of gas the volume varies inversely as the pressure if the temperature is constant;

(2) That the volume varies directly as the temperature if the pressure is constant;

(3) That the pressure varies directly as the temperature if the volume is constant.

The first and third of these laws can be applied to the storage of gases. From (1) above if the temperature is held constant and the pressure is increased, the volume will be proportionally decreased; so that by using high pressures relatively large quantities of gas can be stored in cylinders of small volume and further, the amount of gas stored will be in direct proportion to the cylinder pressure. Both of these facts are employed in the storage of gases for use in miscellaneous aircraft equipment. From (3) above it is seen that the cylinder pressure depends directly on the temperature of the enclosed gas. Care then must be taken in the placement of these storage devices to prevent excessive internal pressures due to increased temperatures.

c. In the application of gases and vapors to miscellaneous equipment, consideration must also be given to the other states of matter (liquid and solid) and the methods of changing matter from one state to another. Most substances change from the solid to the liquid state when sufficiently heated; thus ice changes to water. When sufficiently cooled, liquids change back to solids, e. g., the freezing of water. By application of sufficient heat or a sufficient reduction in pressure most substances change from the liquid state to the gaseous state; thus when sufficiently heated, water changes to steam by ebullition (boiling), and when subjected to a reduced pressure gasoline vaporizes by evaporation. This process is also reversible, for by

either decreasing the temperature or increasing the pressure, or both, substances can be changed from the gaseous state to the liquid state; e. g., the condensation of steam by cooling or the liquefaction of carbon dioxide gas by an increase in pressure. A change of state of a substance directly from solid to vapor or vice versa without first becoming a liquid is called sublimation. Examples of these changes are found in the disappearance of dry snow at low temperatures or the formation of frost from water vapor in the air.

d. It follows then from the above discussion, that substances, which are gaseous at atmospheric pressure can be stored as liquids in an enclosed cylinder, if the temperature of the gas is sufficiently low or the storage pressure sufficiently high. The process is a reversible one so that if a liquid is subjected to a sufficiently low pressure or high temperature, it can be vaporized. Typical examples of these changes are found in the use of carbon dioxide and steam in aircraft equipment, and the formation of ice on the wings of an airplane.

e. In addition to the general properties outlined above each gas has particular chemical and physical properties which render it different from other gases. Therefore the four principal gases and vapors (carbon dioxide, oxygen, air, and steam) used in the miscellaneous equipment described herein, are taken up individually.

f. CO_2 gas (carbon dioxide) has been adopted for use as a means of inflating various pneumatic equipment and as a fire extinguishing agent. This gas is stable, noncorrosive, nonpoisonous, noncombustible, and liquefies at a relatively low pressure which permits the filling of storage cylinders with a greater volume than is possible with other suitable gases. The normal pressures at which CO_2 gas is stored will vary from 700 to 1,000 pounds per square inch. At these pressures from two-thirds to three-fourths of the gas is in a liquid state and, when released to the atmosphere, expands approximately 500 times its liquid volume; 1 pound of the liquefied gas expanding to approximately 9 cubic feet in the gaseous state. The freezing point of the gas is approximately minus 110° F., so that no precautions need be taken to prevent exposure of containers to low atmospheric temperatures. Being noncorrosive it is not injurious to any materials or equipment with which it may come in contact. In addition to being noncombustible, which eliminates the danger of fire hazards in its storage and use, CO_2 is effective in preventing combustion. As low as 16 percent of CO_2 in air will not permit combustion of ordinary combustible materials. This feature makes it a particularly desirable fire extinguishing agent in the case of fires with volatile liquids and gases, such as gasoline, oil, acetylene, etc. It is also a nonconductor

of electricity and is safe to use on equipment charged with high voltages. The high rate of expansion when CO_2 is released from a cylinder so lowers the temperature of the escaping gas that carbonic snow is formed. If this snow, which has a temperature of approximately minus 110° F., comes lightly into contact with the skin, no harm will result; however, if pressed against the skin, or if the escaping gas is blown directly onto the body, a burn similar to that produced by extreme heat may result. In case of such burns, preliminary first aid treatment should be given immediately as for other burns. Immediate application of carron oil (linseed oil and lime water) followed by treatment with picric acid spray or tannic acid is recommended, with subsequent treatment, as necessary by competent first aid or medical personnel.

g. Oxygen is essential in definite quantities for the proper functioning of the human body and since at high altitudes the supply in the air is not sufficient for this purpose auxiliary oxygen must be carried in aircraft to make up this deficiency. Oxygen should be used at all times by every one participating in flights above 15,000 feet. Oxygen should be used when remaining at an altitude below 15,000 feet but in excess of 12,000 feet for periods of 2 hours or longer and in excess of 10,000 feet for periods of 6 hours or longer duration. The normal requirements for oxygen at the various altitudes are listed in table I. These amounts of oxygen will permit the individual to maintain his mental and physical efficiency, prevent fatigue, and prevent injury to the body cells, particularly those of the nervous system which are very susceptible to oxygen want. The amount of oxygen absorbed in the body becomes progressively less during ascent to high altitudes. The result of this shortage of oxygen in the body depends on many factors, the most important of which are as follows:

(1) Altitude attained.
(2) Duration of flight at that altitude.
(3) Amount of physical effort performed.
(4) Inherent altitude tolerance of the individual.

Gaseous oxygen is colorless, odorless, and tasteless and is obtained from the atmosphere by liquefaction or fractional distillation. It is placed through a purifying process before being placed as a charge in the oxygen cylinders for use in aircraft breathing equipment. Breathing oxygen is nonpoisonous, has no deleterious effect on the teeth or dental restorations, and there are no ill effects in taking more than the prescribed amount other than to deplete unnecessarily the available supply. An individual moving about in an airplane and

doing light work will require approximately twice the amount of oxygen as when seated quietly. The administration of oxygen, when needed, should be continuous since there is no storage of this gas in the body, except a small amount in the lungs and blood which is normally expended within approximately 40 seconds. Table I takes the above facts into consideration, the smaller value of flow being the average amount necessary for a pilot or observer during normal flying, while the greater value is the average amount needed for a pilot carrying out maneuvers or for an observer swinging a gun, camera, etc.

TABLE I

Altitude in feet	Oxygen flow, liters of gas per minute
10, 000	2. 1 to 4. 5
15, 000	3. 9 to 7. 7
20, 000	5. 4 to 11. 0
25, 000	7. 4 to 15. 1
30, 000	10. 1 to 20. 2
35, 000	13. 0 to 26. 0

h. Air is used in aircraft de-icing systems to periodically inflate rubber shoes for the purpose of breaking up ice formations on airplane wings, tail surfaces, radio loop and masts, and for the conduction of heat in aircraft heating systems. Air, in the atmosphere, contains a small percent of water vapor and may contain moisture in the form of droplets. Water vapor and droplets may exist in their respective states (gaseous and liquid) at air temperatures below freezing and, depending on certain temperature and turbulence conditions, may produce solids upon contact with stationary or moving objects. These solids may be classified as follows: Frost, rime or granular ice, and glaze or clear ice. The presence of any one of these on the airfoils of an airplane may seriously affect the aerodynamic characteristics of the airplane, or cause excessive vibration. The formation of frost is a direct transformation of water vapor to the solid state (sublimation) and depends on—amount of water vapor present in the air, temperature of the air, and temperature of the surface on which the frost is formed. Rime is formed, when an under-cooled water particle hits a solid object and immediately freezes, the rate of deposition depending on the degree of under-cooling. Since this action is the freezing of the individual droplets, the result is an opaque granular formation building up on the leading edges of the structure. The

formation of glazed or clear ice is due to freezing temperature aided by evaporative cooling.

i. Steam used in aircraft heating systems is, of course, produced by raising the temperature of water above its vaporization or boiling point. When heat is applied to an enclosed vessel or boiler having a small steam outlet and containing water at atmospheric pressure, steam bubbles will be formed when the temperature of the water reaches 212° F. As steam is generated faster than its escapes, the pressure and temperature of both water and steam will rise. This increased pressure serves to force the steam to surfaces where it is utilized in transferring heat to the air at a lower temperature. This transfer of heat cools the steam and returns it to a liquid state by condensation, when its temperature drops to a given value.

39. Storage.—*a.* Steel cylinders are used for the storage of oxygen and carbon dioxide. The identifying colors of the cylinders and the stencil colors are given in the following table:

TABLE II

Cylinder	Identifying color	Stencil color
Oxygen	Green (shade No. 7)	White.
Ground fire extinguisher, CO_2	Red	Do.
All other CO_2 cylinders	Aluminum	Black.

b. These cylinders are of seamless steel and are supplied in various weights, shapes, and capacities depending on—the type of gas being stored, the use to be made of the gas, and the particular installation in which the cylinder is to be placed. They are constructed to withstand pressures of several thousand pounds and will therefore hold fairly large quantities of gas. They may be classified as lightweight for installation in aircraft, and a heavier weight for ground use. Cylinders for aircraft use can be identified by their hemispherical ends, while those for ground use have flat bases. Discussion will be limited to cylinders of the first type, in which carbon dioxide and oxygen are stored for use in aircraft equipment. As the storage of these two gases present different problems, they will be treated separately.

c. CO_2 cylinders, in addition to the markings required by Interstate Commerce Commission regulations, are marked to provide the following information:

Weight empty (including valve or safety disk bushing),
Weight fully charged,
Rated CO_2 capacity,
Name of gas (carbon dioxide),
Type of syphon tube installed.

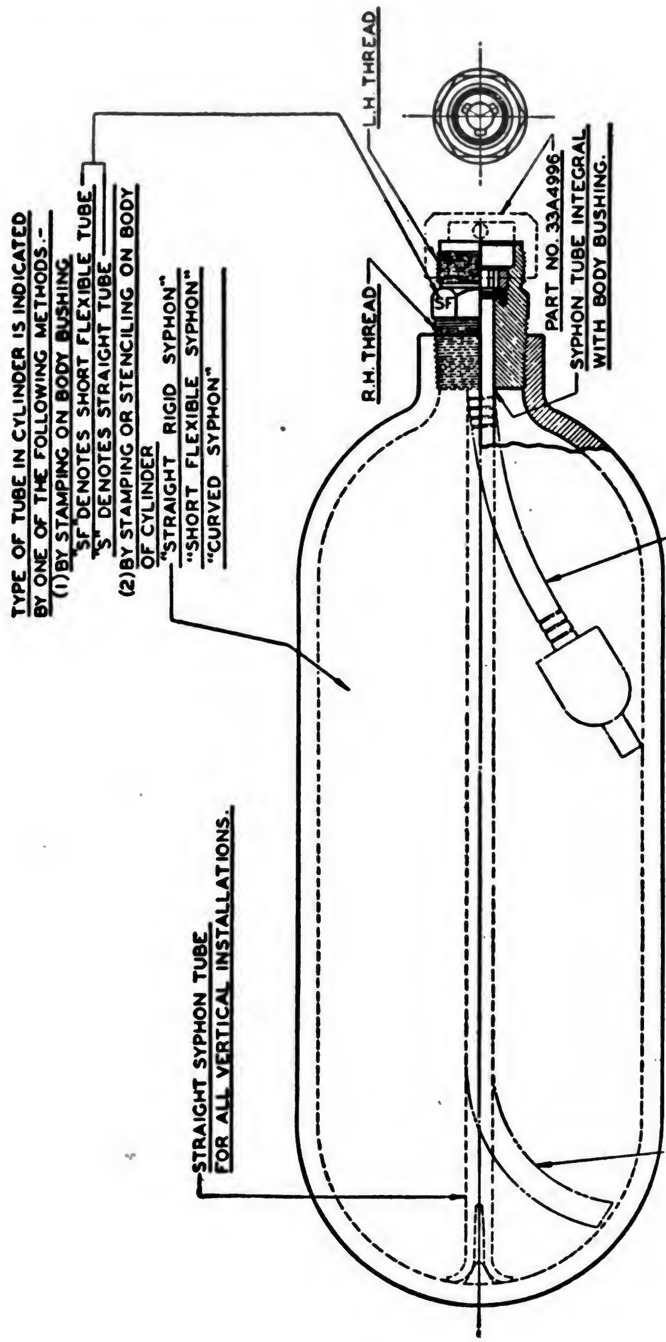

FIGURE 37.—CO_2 cylinder showing syphon tubes.

In carbon-dioxide cylinders from two-thirds to three-fourths of the charge is in a liquid state, the remainder being in a gaseous form at the highest point in the cylinder. Syphon tubes attached to the body bushing and running to the lowest part of the cylinder are used to allow only liquid to pass through the release valve and thus prevent the formation of carbonic snow and the consequent clogging of passages. There are three types of syphon tubes in general use as shown in figure 37:

(1) The straight rigid type which is used on cylinders mounted in a vertical position.

(2) The short flexible type which is used on cylinders mounted in a horizontal position.

(3) The curved rigid type used on cylinders having no fixed mounting position.

In order to identify readily the type of syphon tube furnished with each cylinder, the following markings are stamped on the main body bushings of each cylinder: "S" means that the cylinder is equipped with a straight rigid syphon tube that extends to the bottom of the cylinder. As a further identification the word "vertical" is also stamped on the cylinder. "S. F." means that the cylinder is equipped with a short flexible syphon tube that extends only to the end of the upper spherical portion of the cylinder. As a further identification the word "horizontal" is also stamped on the cylinder.

d. All CO_2 cylinders are equipped with safety disks designed to rupture at a pressure of 2,200 to 2,800 pounds per square inch, which is below the test pressures to which each cylinder is subjected. As the pressure of CO_2 in the cylinder rises rapidly with increases in temperature, charged cylinders should not be exposed to the direct rays of the sun, or where the temperature will exceed 130° F. It is therefore advisable to enclose charged cylinders in suitable containers during shipment to prevent exposure to the direct rays of the sun. The various type valves employed on CO_2 cylinders will be discussed with the particular equipment with which they are used. The cylinder charge or amount of CO_2 contained in the cylinder can be determined only by weighing. If a cylinder shows a loss of charge when weighed for inspection, it is an indication that a leak exists and the cylinder is removed from service and replaced. The leaking cylinder can be returned to a commercial supply house or service-control depot for recharging. The following table shows the CO_2 charge in pounds with the permissible variation for the various aircraft installations presented in this manual.

TABLE III

Use	CO_2 charge (maximum) pounds	Permissible variation (less than maximum charge)	
		Pound	Ounces
Hand type, aircraft fire extinguishers, type A-14	3. 62	0. 20	3. 20
Hand type, aircraft fire extinguishers, type A-15	2. 00	. 12	1. 92
Fixed installation, aircraft fire extinguishers, type A-11	5. 00	. 25	4. 00
Fixed installation, aircraft fire extinguishers, type A-12	7. 25	. 43	7. 00
Fixed installation, aircraft fire extinguishers, type A-13	7. 25	. 43	7. 00
Raft, type A-1	3. 25	. 03	. 50
Raft, type A-2	3. 25	. 03	. 50
Raft, type B-1	1. 25	. 01	. 20
Raft, type B-2	1. 25	. 01	. 20
Raft, type B-3	1. 25	. 01	. 20
Raft, type C-1	. 90	. 01	. 20
Vest, type B-3	. 018	------	------

e. The oxygen cylinder for use with high altitude breathing apparatus consists of the lightweight seamless steel cylinder described above with a double-seat hand shut-off type oxygen valve. The main body of the valve is provided with an outlet for coupling to the system and a secondary outlet fitted with a plug of fusible metal which will melt at 212° F., also a frangible gold safety disk which is designed to rupture at 2,350 to 2,900 pounds per square inch pressure. A syphon tube on the bottom of the valve extending part way into the cylinder helps to prevent rust or foreign particles from getting onto the valve seats. As the charge of oxygen is completely in a gaseous state the amount of gas in the cylinder is directly proportional to the pressure. The state of charge can therefore be determined at any time by noting the cylinder pressure. The following are examples:

State of charge:	Pressure pounds
Full	1, 800
¾	1, 350
½	900
¼	450

f. Repairs to aircraft type gas cylinders or the removal of body bushings or valve bodies which are threaded directly into the cylinders should be done by the manufacturer or a service-control depot. Repainting of cylinders to renew the finish is done as needed. All cylinders used for the storage of gases are subject to a 5-year or quinquennial hydrostatic test. Since those used for the storage of CO_2

and oxygen in aircraft are frequently transferred between airplanes and activities, the only record of the time of this test is a marking stamped on the cylinder; e. g., 6-40. The time of the next quinquennial test for these cylinders is checked on installation and at periodical inspections. Cylinders that require this test are reported to the control depot 3 months, in the case of oxygen, and, 6 months, in the case of the CO_2, in advance of their due date. They are removed from service and replaced. The date of each weight (charge) inspection of aircraft type CO_2 cylinders is stenciled on the cylinder in black letters not to exceed ¾ inch high. The date of the initial installation inspection is preceded by "Inst" and that of the 6-month inspection by "6 month Insp." In case the inspection date as stenciled on cylinder is obscured, due to mounting position of cylinder, the inspection record is maintained on a card fastened to the cylinder.

SECTION VI

FIRE-EXTINGUISHING EQUIPMENT

	Paragraph
General	40
Fixed type carbon dioxide	41
Portable type carbon dioxide	42
Portable type carbon tetrachloride	43

40. General.—*a.* Fire extinguishers used in aircraft are of two general types: the fixed type fire extinguisher which is a built-in system employing carbon dioxide, and the portable or hand type fire extinguisher using either carbon dioxide or carbon tetrachloride.

b. The carbon dioxide fire extinguishers are particularly effective in combating gasoline or oil fires. However, if fabric, wood, etc., are involved, the carbon tetrachloride extinguishers may be used alone or in conjunction with the carbon dioxide extinguisher.

c. The extinguishing equipment carried on aircraft is adequate for combating incipient fires only, and the extinguishers, regardless of type, should accordingly be put into action as soon as possible after the fire starts. The following instructions are included as a guide in fighting fires in airplanes:

(1) *Engine, fuel tank, and amphibian hull fires.*—If the airplane is equipped with a built-in fire extinguishing system, set the distributor valve to the proper position as soon as the location of the fire has been determined and pull the release handle. In the case of an engine fire, first shut off the supply of gasoline to the engine and then fully open the throttle. Open all emergency exits.

(2) *Wing fires.*—Turn all switches controlling landing or navigation lights to the OFF position. Open emergency exits.

(3) *Cabin fires.*—Close all windows and ventilators. Use hand fire extinguisher on the fire. When using the quart carbon tetrachloride hand fire extinguisher in confined spaces, stand as far from the fire as possible. The effective range of the extinguisher is approximately 30 feet. Immediately after using the extinguisher, open windows and ventilators. In the case of an electrical fire, turn the main switches off, and in the case of a leaking fuel or oil line, shut off the valves.

d. While carbon dioxide (CO_2) is a nonpoisonous gas and breathing it will not adversely affect a human being either at the time it is inhaled or afterward, carbon tetrachloride is a volatile fluid, the gases of which when inhaled in large amounts act as an anesthetic, causing drowsiness, dizziness, headache, excitement, anesthesia, and sleep. Any one or all of these symptoms may occur. In case any odor of carbon tetrachloride is detected while flying, an investigation to determine its source should immediately be made. If it is found that a fire extinguisher is leaking, it should be corrected at once. When sprayed on a fire, carbon tetrachloride produces phosgene. The inhalation of even a small amount under such conditions may produce harmful effects and, if a sufficient quantity is taken into the lungs, the results may be fatal. Breathing the fumes when using the fluid on a fire should therefore be avoided.

41. Fixed type carbon dioxide.—*a.* The purpose of this fire extinguisher is to provide a means of flooding an engine compartment, amphibian hull, or gasoline-tank compartment with CO_2 gas in case of fire in those regions. A distributing valve mounted within easy reach of the pilot is set to direct the gas to the desired location, and a pull handle is operated to release the gas from the cylinder. The operating controls of this equipment are clearly marked to indicate their correct use.

b. Fixed-type CO_2 fire extinguishers are supplied under three different designations, namely, single-discharge line; two-discharge line; and three-discharge line. These are used on single-, twin- and three-engine airplanes respectively. The single-engine fixed-type fire-extinguisher system consists of the following elements: Pull handle; CO_2 cylinder; release valve; supply tubing; distributing tubing; and in some cases, carburetor nozzle. Schematic drawings of this system for the air-cooled and liquid-cooled engines are shown in figures 38 and 39. The multiengine installations have the same component units as the single-engine installation with additional tubing,

carburetor nozzles, a distributing valve, and a cylinder of larger capacity. A schematic drawing of the three-engine installation is shown in figure 40.

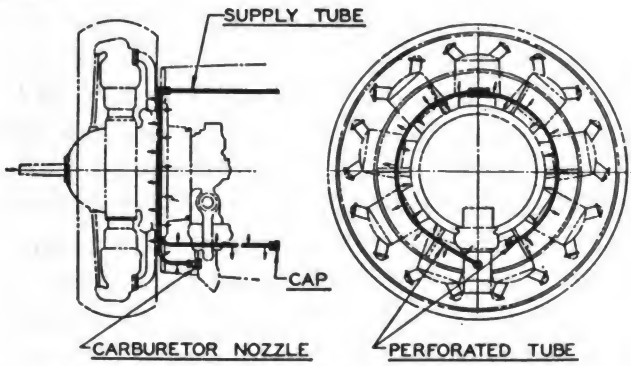

FIGURE 38.—Tubing installation, air-cooled engine.

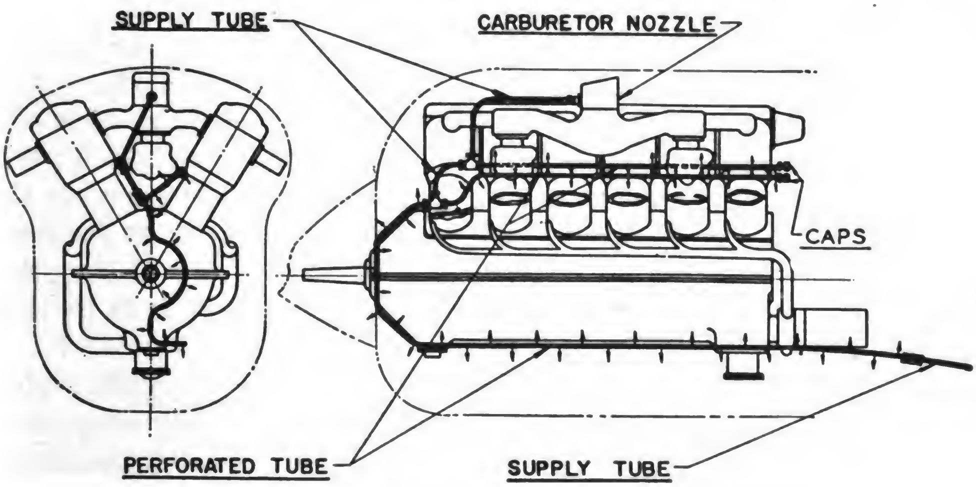

FIGURE 39.—Tubing installation, liquid-cooled engine.

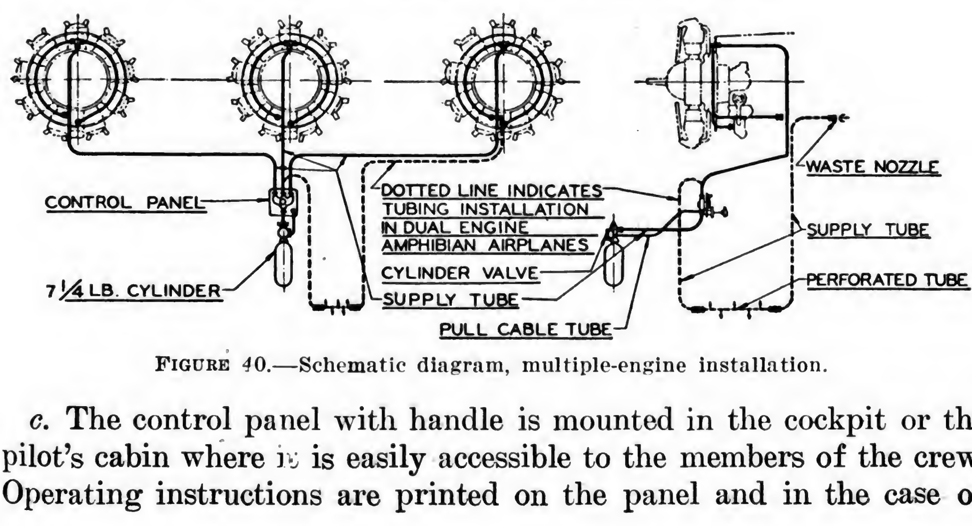

FIGURE 40.—Schematic diagram, multiple-engine installation.

c. The control panel with handle is mounted in the cockpit or the pilot's cabin where it is easily accessible to the members of the crew. Operating instructions are printed on the panel and in the case of

multiengine systems the settings for the distributing valve are also noted.

d. The type CO_2 cylinder used is that specified in table III for the particular fixed-type fire extinguisher being used. The mounting position of the cylinder is as follows:

(1) If equipped with a straight syphon tube the cylinder is mounted vertically to the thrust line, but may be tilted 30° forward or aft of this position.

(2) If equipped with a short flexible syphon tube the cylinder is mounted parallel with the thrust line with the valve end aft, but may be tilted 30° below this position at the valve end.

e. Fixed type fire extinguisher systems employ either the cutter type valve or the quick release type valve on the CO_2 cylinder. The cutter type valve assembly (fig. 41) is screwed directly onto the body bushing and consists briefly of the cutter valve body which houses the piston cutter and the piston actuating spring. The upper portion of the cutter extends outside of the cutter valve body. The entire piston is bored out hollow from the cutter end to a short distance beyond its extension outside of the cutter valve body. At this point it terminates in four relief ports, which vent the gas to the atmosphere on a premature discharge. A red indicator is fastened to the upper end of the piston and a celluloid cap is placed over this indicator. This cap is such that when the cutter valve is in its normal set position, the red indicator is covered from sight. Upon operation of the cutter valve, the piston travels downward bringing the red indicator into view, thereby giving a visual indication that the cylinder has been discharged. Should an abnormal temperature cause the safety disk to burst, the gas would travel up through the tubular cutter, then through the bore in the piston and out the relief ports, which in turn would burst the celluloid cap, allowing the gas to escape into the atmosphere through this channel rather than through the discharge line and distributing system to the engine. In this case the red indicator would be exposed to view denoting that the cylinder had lost its charge. The control handle in the cockpit is connected by means of flexible cable in tubing to the manual release lever on the cutter valve. The manual release lever can be rotated about 15° after which continued rotation allows the camshaft in the cutter valve body to rotate freely. The piston spring then forces the piston down, thereby cutting the disk, which releases the gas. When the piston is forced down by the spring, the relief ports fall below the reset nut into the spring chamber, which causes the gas to pass through the tubular cutter into the bore of the piston, thence through

the relief ports into the spring chamber, and thence to the supply tubing.

f. The quick release type valve consists of a valve body containing a retainer assembly which includes an operating handle with a notched cam and hollow valve stem. Figure 42 shows the valve

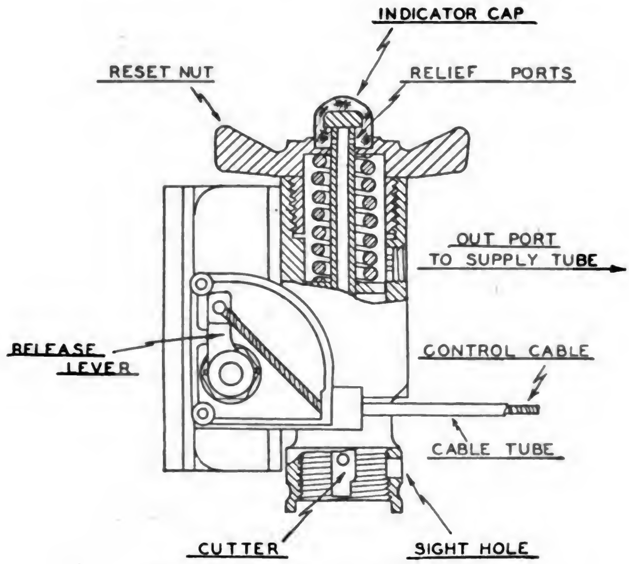

FIGURE 41.—Cutter type valve.

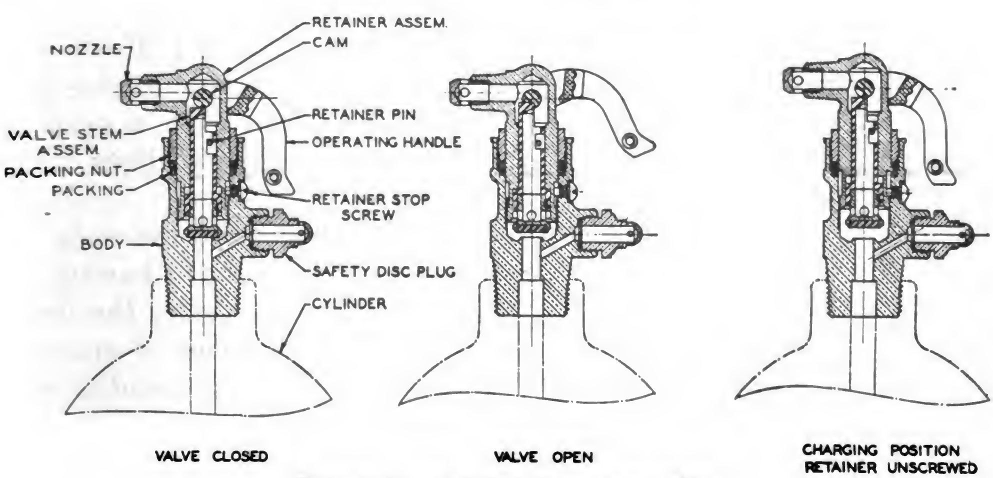

FIGURE 42.—Quick release type valve.

assembly. With the retainer screwed down and with the handle down, the valve is held on its seat by the cam in the operating handle. When the handle is raised, as shown in the middle view, the cam rotates so that the gas pressure on the valve seat can force the valve stem into the notch in the cam and the CO_2 gas is released through the syphon tube and the hollow valve stem to the nozzle of the valve

and thence to the supply tubing. To reset the valve the retainer must be backed off to a position shown on the right view of figure 42 and the handle placed in the down position before the valve can be reseated. The retainer assembly is then screwed down until the valve stem is on the seat.

g. The distributor cock used on the multi-engine fixed-type extinguisher directs the output of the CO_2 cylinder to the particular engine or compartment for which the setting is made on the control panel. The valve itself is a three- or four-port rotor type selector valve mounted on the rear of the control panel.

h. The supply tubing is of aluminum alloy having an outside diameter of ½ inch and a 0.032-inch wall thickness. The fittings are also of aluminum alloy. Bends in the supply-line tubing are limited to radii greater than three times the outside diameter of the tubing or in this case 1½ inches.

i. The tubing and fittings of the distributing lines are similar to the above, except that the tubing is drilled with small perforations for the proper discharge and distribution of the CO_2 gas to the areas being protected. The distributing system for the air-cooled and liquid-cooled engines are shown respectively in figures 38 and 39, the arrows indicating the discharge of the gas through the perforations. On some installations, additional protection is provided for the carburetor by a circular length of perforated tubing running from the main engine system around the carburetor, or a direct line running to a carburetor nozzle located in the carburetor intake just below the butterfly valve. If the engine is mounted in a nacelle, added protection is sometimes furnished by running two lines from the main system to the rear end of the nacelle.

j. Operation of the fixed-type fire extinguisher in the case of engine installation is accomplished by pulling the control handle on the control panel. Through the control cable this actuates the lever on the cylinder-release valve and the CO_2 gas in a liquid state is forced under cylinder pressure through the supply tubing, and thence to the distributing system tubing. Vaporization of the liquid occurs as the CO_2 passes through the perforations in this tubing and streams of carbon-dioxide gas are forced into the engine region. In the case of the multiengine installations, it is necessary to first set the distributing cock to the proper setting on the control panel and then pull the control handle, which performs the same function as described above.

k. In case the release valve cutter becomes dull or deformed it is replaced, never sharpened, as this might shorten it to a degree that it

could not reach the sealing disk. In case the perforations in the distributor tubing become clogged, the holes are opened up and a stream of compressed air is directed through the tubing from the inside. The release valve control cable is packed in graphite grease.

FIGURE 43.—Portable type carbon dioxide fire extinguisher.

42. Portable type carbon dioxide.—*a.* This CO_2 extinguisher (fig. 43) unlike the fixed type previously described may be used to combat fires in any part of the airplane.

b. The component parts of this extinguisher are as follows:

(1) A CO_2 cylinder having the capacity specified in table III for this extinguisher, and equipped with a carrying handle.

(2) A quick release type valve of a design similar to that described and illustrated in the previous discussion of the fixed type CO_2 fire extinguisher.

(3) A flexible hose equipped with threaded fittings for connection to the valve outlet and conical horn.

(4) A conical horn equipped with wooden handle and containing a discharge orifice which serves to restrain the liquid CO_2.

c. The operation of the extinguisher is accomplished by merely pulling up the release handle. Since the released carbon dioxide is at an extremely low temperature, care must be taken in operating this type of extinguisher not to touch the conical horn.

43. Portable type carbon tetrachloride.—*a.* This extinguisher (fig. 44) is a 1-quart hand-operated type which expels the liquid by air pressure. Pressure to discharge the liquid is obtained by means of a hand-operated air pump forming an integral part of the extinguisher. The extinguisher employs carbon tetrachloride (CCL_4) as the extinguishing medium. This chemical is a nonconductor of electricity and may be safely used on fires where electric current is involved. It has an effective range of from 20 to 30 feet and its effectiveness is not altered by low temperatures.

b. The housing of this fire extinguisher is a brass cylinder which contains a hand pump unit incorporating a check valve. The unit is 13½ inches high and 3 inches in diameter and weighs 7 pounds fully charged. The mechanism is such that the pressure compounds and continuous pumping are unnecessary and the ease with which the pump may be worked enables the operator to direct the stream with greater efficiency.

c. This type fire extinguisher may be mounted either horizontally or vertically. When mounted in a vertical position, the nozzle or discharge end is at the bottom. Those that are accessible both from within aircraft and from the ground are, wherever possible, located on the side of the aircraft normally approached for entrance, that is, on which steps, doors, etc., are installed.

d. The life of an extinguisher can be materially lengthened if it is kept filled, wiped free of dust, dirt, and grime. Periodic inspections are made in order to insure that the pump action has not been impaired by internal corrosion, and that each extinguisher will function properly when required in an emergency. These should include sufficient operation of the pump to determine its serviceability. The contents are discharged into a clean glass container. If the liquid is milky and brownish in color it is usually due to the use of impure liquid or the introduction of water which has caused corrosion. If

the liquid is clean and clear it may be returned to the extinguisher by removing the filler cap and pouring it back with the aid of a small clean funnel. When one full quart is returned the filler cap is re-

FIGURE 44.—Portable type carbon tetrachloride extinguisher.

placed and tightened down as the escape of air pressure around the filler cap will reduce the pressure which expels the liquid onto the fire. If the pump works hard a few drops of neat's-foot oil dropped

on the piston rod will find its way down to the leather cup on the piston and soften and restore its life. In case the pump shaft is stained with corrosion, it is cleaned with metal polish and then coated with soft cup grease.

Section VII

FLOTATION EQUIPMENT

	Paragraph
General	44
Pneumatic rafts	45
Pneumatic life preserver vests	46

44. General.—*a.* The types of flotation equipment carried in aircraft are pneumatic rafts, pneumatic vests, and airplane flotation gear, of which only the first two will be discussed.

b. Because such large volumes can be conveniently stored in a small cylinder, CO_2 gas is used for the inflation of this equipment. The capacities of the cylinders used in each case and the weight of the CO_2 charge are given in table III.

45. Pneumatic rafts.—*a. Types.*—These rafts are designed to be carried in aircraft engaged in overwater flights. The pneumatic rafts in use at the present time are—

Type A (1,000 pound capacity).
Type B (400 pound capacity).
Type C (250 pound capacity).
Type D (2,000 pound capacity).

Early models of the rafts were constructed of rubberized fabric, with integral tubular gas cells or compartments, equipped with valves and manifolding for CO_2 inflation. The rafts have an outer covering of rubberized fabric and removable latex-rubber tubular gas cells or compartments equipped with valves and manifolding for CO_2 inflation. A typical raft is shown in figure 45. Each raft is furnished with a waterproof carrying case, sufficient in size to store the deflated raft and the accessories.

b. Accessories.—The following accessories are kept in each raft carried in aircraft; one carrying case, two oars, one hand pump, one repair kit, 40 feet of 75-pound lashing cord, and one emergency signal kit. The kit is filled each time the raft is placed on the airplane and contains one pyrotechnic pistol and six red parachute distress signals. When these items are placed in the signal kit container, the folds in the top of the container are cemented down with two coats of rubber cement. The sealing strip is then cemented down across the opening edge with two coats of rubber cement. In view of the danger involved in the storage of pyrotechnics the above items

are returned to their proper stores when the raft is removed from aircraft and returned to stock.

c. Inflation.—Two types of release valves are employed, namely; combination cutter and hand-shut-off type and a combination hand-shut-off quick-release type. Operation of the first type is accomplished by raising the valve handle which breaks the safety wire, and turning the handle 180° clockwise or in the direction indicated by the

FIGURE 45.—Inflated pneumatic raft.

arrow on the top of the valve. This movement sends a cutter through a safety disk releasing the CO_2 gas. The gas flow can be shut off from the raft at any time by turning the valve in the opposite direction as far as it will go. The second type valve is operated by simply pulling a toggle cord, which raises a handle and allows a spring loaded valve stem to rise. The gas flow can be shut off by screwing down the valve stem as far as it will go. The specified charge in cylinders for rafts is such as to inflate the rafts to 1 pound per square inch gage pressure at 70° F. Due to its low temperature, the initial pressure of the gas in the raft is less than this, but it will increase gradually until it reaches atmospheric tem-

perature, usually in about 10 to 15 minutes. If at any time the gas cell appears to be inflated too tightly the pressure may be reduced by opening the topping off valve. As soon as the pressure is sufficiently reduced, these valves are securely closed. The amount of inflation should be just sufficient to maintain a well rounded contour of the gas cells. If the raft is under-inflated, either initially or because of gas-cell leakage, the hand pump is attached to the topping off valve, and each gas cell further inflated by hand. The repair kit furnished with each raft contains rubber cement and patch material

FIGURE 46.—Raft being deflated.

for repairing leaks whenever necessary. The pneumatic seats are generally provided with a valve on the side or the bottom side of the seat for inflation with the hand pump.

d. Deflation.—Deflation of the raft is accomplished by unscrewing the topping off valves on each gas cell, opening each seat valve, and folding and rolling the raft to completely expel all gas. The raft is completely deflated, the discharged cylinder replaced with a charged one, and all valves secured before the raft is placed in the carrying case.

e. Folding.—The operations for properly folding are shown in figures 46, 47, 48, and 49. Where practicable, the external surfaces of the rubberized fabric are thoroughly powdered with talc before folding.

FIGURE 47.—Deflated raft being folded.

FIGURE 48.—Final folding operation.

f. Repairs.—No repairs are made to the rubberized fabric or latex bladders other than the patching of small holes. Such repairs are made by patching the bladder with rubber cement and bladder material and the casing with rubber cement and rubberized fabric, all supplied in the repair kit. Rafts having large tears, rips, and se-

FIGURE 49.—Raft and accessories being placed in carrying bag.

verely chafed areas are condemned. When cylinder connections, manifold, and topping off valves are found defective they are repaired or replaced as required.

g. Inspection.—The date of each 6 months' raft inspection is stenciled in indelible ink to the right of the inspection patch as viewed from the end of the raft, on which the CO_2 cylinder is mounted, using letters and figures approximately one-half inch high; for example: Tested 12-8-38.

h. Storage.—Rafts, when not in use on aircraft, are unfolded and stored away from light in a cool, dry location favorable to the storage of rubber articles.

i. Age.—The age limit of rafts is from 3 to 4 years depending upon the particular type and model. Consult Technical Orders for further information of this nature. The date of manufacture is stenciled on each raft.

FIGURE 50.—Life-preserver vest.

46. Pneumatic life-preserver vests.—*a. Type.*—The current type pneumatic vests, shown in figure 50, is designed primarily for use under climatic or other conditions that render the wearing of kapok filled or similar types of buoyant garments undesirable because of their discomforting bulk or heat-retaining qualities. However,

if maximum safety is desired, regardless of these discomforts, the kapok filled life preserver vest should be used instead of the pneumatic type. The pneumatic life preserver vest consists of a double compartment cotton fabric outer casing, enclosing two separate latex rubber cells. Buoyancy for emergency use is obtained by inflation with CO_2 gas, two CO_2 cylinders (one for each compartment) being provided for this purpose. CO_2 cylinders for use with this life preserver vest are not rechargeable. The vest is to be worn deflated under the parachute harness. At no time, however, is it worn under tight fitting clothing.

b. Inflation.—The vest is inflated by pulling downward on the cord attached to the two discharge levers. This actuates both plungers and punctures the sealing caps on the two CO_2 cylinders. If inflation of both compartments does not occur simultaneously, an additional pull on the cord may be required before both of the sealing disks are punctured. Additional inflation, if necessary, may be effected by opening the valves at the neck of the vest and blowing with the mouth. When placing the CO_2 cylinders in the containers, the ends of the cylinders containing the sealing caps must be inserted first, with the discharge levers in a vertical position and safetied with light safety wire against the side of the container to prevent premature discharge of the cylinder as the container cap is being secured in place. The cap should always be tightened firmly by hand to prevent leakage.

c. Deflation.—Deflation is accomplished by opening the mouth valves and slowly rolling up the vest.

d. Storage.—When not in use life-preserver vests are kept in their original container and stored in a cool, dry storage room.

e. Repair.—Repair of leaks or punctures in the latex rubber cells is made by first removing the stitching of the fabric outer casing near the leak and applying standard Air Corps cold patch. The rubber cell is then tested for leakage by inflating and submerging in water. If the leak has been satisfactorily repaired the outer casing is replaced and restitched. Snagged or chafed spots in the fabric outer casing may be repaired by sewing a patch of 6-ounce cotton fabric over the damaged area, provided the patch does not exceed 2 square inches in area.

f. Inspection.—The date of each 6-months' inspection is stenciled in indelible ink on the vest; for example: Insp. 6-23-40.

g. Age.—Vests are considered unserviceable and disposed of 3 years after the date of manufacture stamped on each vest. CO_2 cylinders that are removed from unserviceable vests are returned to stock.

Section VIII

OXYGEN EQUIPMENT

	Paragraph
General	47
Description	48
Operation	49
Maintenance	50

47. General.—Oxygen equipment in aircraft is used to supply flight personnel with the necessary oxygen to make up the deficiency in the atmosphere at high altitudes. In all but exceptional cases, individual instruments for the regulation of supply are provided for each person participating in the flight and the systems have a flexibility in that two users may be supplied from a common source or, in the case of extended flights at high altitudes, two cylinders may be used to supply one person.

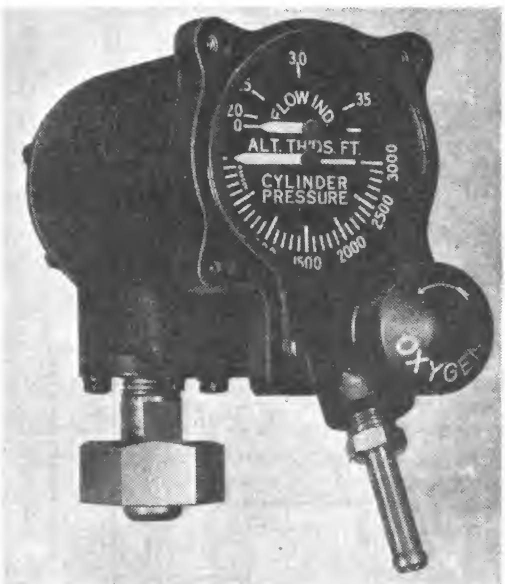

Figure 51.—Oxygen regulator.

48. Description.—Although the quantity of equipment varies with the particular airplane, the basic units in aircraft installations include regulator, supply cylinder, high pressure tubing and manifold connections, low pressure tubing, and mouthpiece or mask.

a. Regulator.—The current type oxygen regulator is used to control accurately and to supply oxygen needed by personnel engaged in high altitude flights. The instrument for use with compressed oxygen is manually operated and incorporates a sensitive flow metering device combined with an accurate indicator. The standard model

is adjusted to supply the amount of oxygen normally required at high altitudes. Figure 51 shows a view of the assembled instrument. Figure 52 shows a schematic diagram of the internal mechanism. A relief valve is provided in the back cover to protect the mechanism against over-pressure in case of failure of the regulating valve.

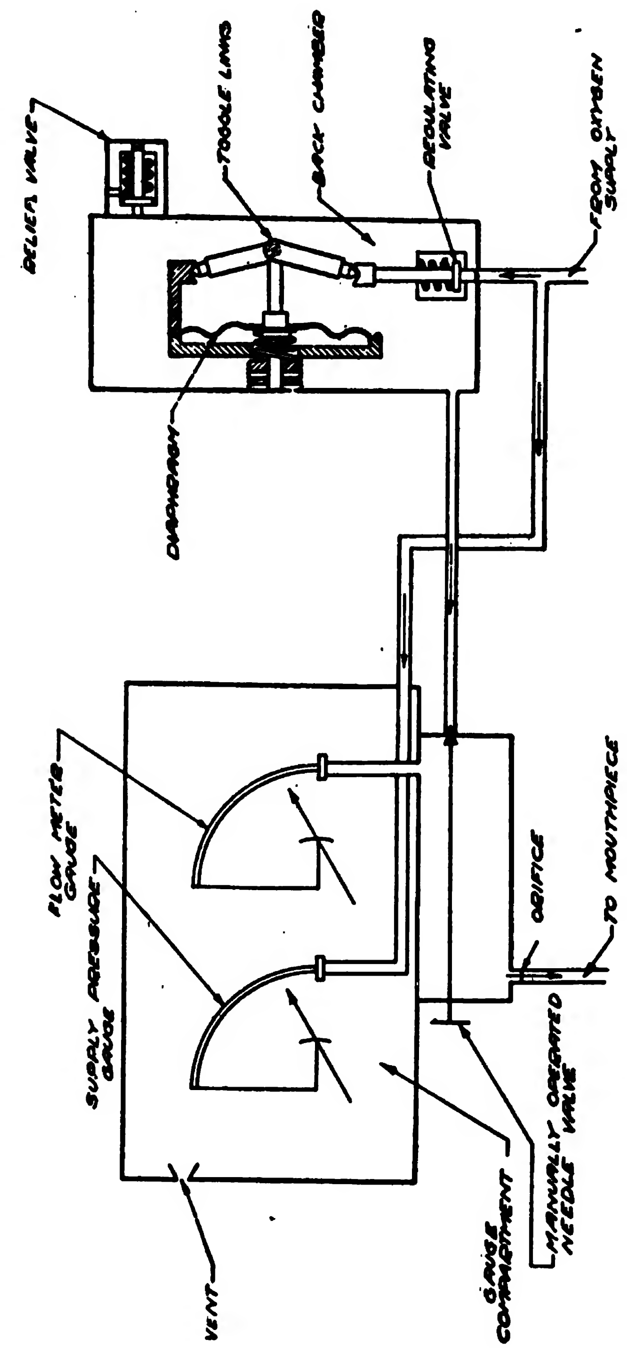

FIGURE 52.—Schematic diagram of oxygen regulator.

This valve is set and locked by the manufacturer. The dial is marked directly in altitude for simplification, the proper flow for any altitude being obtained when the pointer is set at the corresponding graduation by opening or closing the needle valve. The cylinder pressure indicator is connected directly to the line from the oxygen tank. This unit shows the condition of the supply at a glance.

b. Cylinders.—There are four standard lightweight types of oxygen supply cylinders for aircraft use as shown in the following table:

TABLE IV

Type	Weight empty maximum (pounds) with valve	Weight filled (pounds)	Oxygen delivered at 1,800 pounds	
			Cubic feet	Liters
B	11. 45	13. 3	21	590
C	15. 45	19. 9	27. 5	780
D	18. 2	21. 5	36. 5	1, 030
E	23. 2	27. 4	46	1, 300

The storage of oxygen and the details of the cylinder are discussed in section V.

c. Connections.—(1) The high pressure tubing is of seamless copper, silver soldered to the connector fittings, and is used to connect the outlet of the regulator with the mouthpiece or mask. Manifold connections made of the same material are employed to provide connection of two regulators to one cylinder or one regulator to two cylinders.

(2) The low pressure tube (type B–1) is constructed of flexible armored tubing and is used to connect the outlet of the regulator with the mouthpiece or mask. This assembly is available in two standard lengths, 3 and 6 feet.

49. Operation.—If the oxygen valve cannot be reached during flight, it is turned on before the take-off when flights over 10,000 feet are contemplated. In order to relieve the pressure on the regulator, the cylinder valve is closed again on landing. The operation of the needle valve to regulate the rate of flow during flight is discussed in paragraph 48*b*.

50. Maintenance.—At the completion of flight, mouthpieces or nipples on the ends of the supply tubing assemblies are sterilized by immersing in a cresol solution for 5 minutes and thoroughly rinsing, both inside and outside, in pure water. In checking the operation of oxygen equipment, it should be noted that a properly working regulator will give a flow indication of at least 35 as the needle valve is

fully opened for any cylinder pressure from 500 to 2,100 pounds per square inch. At regular periods the regulator is removed and calibrated. Oxygen cylinders are stored in a cool, dry place and away from any oil or grease. A mixture of litharge (red lead oxide) and glycerin is used for sealing the threads at connections. Oil and grease under no circumstances are to be applied on any connections, packings, valves, gages, or other oxygen equipment. Failure to observe this precaution may result in an explosion. Castile soap may be used on the threads of the needle valve in case lubrication is required.

SECTION IX

ICE ELIMINATING EQUIPMENT

	Paragraph
General	51
Description	52
Operation	53
Maintenance	54

51. General.—De-icer systems are used to prevent the continued accumulation of ice on airplane wings, tail surfaces, radio loop, and masts. This is accomplished by the periodic inflation of rubber shoes attached to the leading edges of these units.

52. Description.—*a.* De-icer systems can be classified as those served by one vacuum pump (single-engine airplane) and those served by two vacuum pumps (multiple-engine airplanes). In general, the de-icer system for the single-engine airplane employs the following units: a vacuum pump, an oil separator, an air-control valve, an air-filter unit with relief valve, an electrically driven distributor valve, and the inflatable rubber shoes and connecting tubing. A schematic drawing of this system is shown in figure 53.

b. The discharge side of an engine-driven vacuum pump is used to provide the operating pressure of the de-icer system. These pumps are usually of the rotary, four-vane positive-displacement type and are lubricated from the engine oiling system.

c. The purpose of the oil separator is to remove the oil from the pump discharge and return it to the crankcase. It is usually made of brass and has tube connections for inlet, air discharge, and oil outlet. It contains no moving parts and in most types incorporates a strainer, also a restriction in the oil outlet.

d. The control valve is essentially a selector valve having two settings: the on position which directs the discharge of the pump to the system, and the off position which directs the pump output to the atmosphere or engine exhaust stack.

e. The air filter is an auxiliary separator used to purge the air of the excess oil not removed by the main oil separator, and the condensed oil vapors accumulated in this part of the system before it is directed by the distributing valve to the rubber shoes. This is accomplished by passing the air from the inlet at the bottom through a chamber of copper wool and a perforated strainer to the outlet at the top of the filter. A system relief valve is incorporated in the oil outlet at the base of the filter. This valve controls the operating pressure of the de-icer system and is generally set to open at a pressure of 7 pounds per square inch.

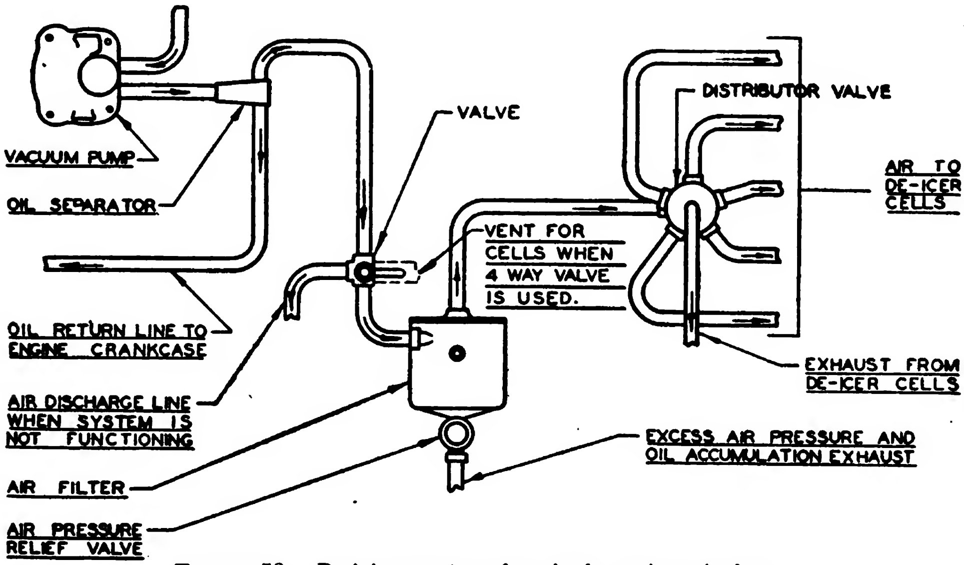

FIGURE 53.—De-icing system for single-engine airplane.

f. The purpose of the distributing valve is to furnish air periodically under pressure to each of the cells of the rubber shoes. The rotor of the valve is driven by a fractional horsepower motor through a set of reduction gears, the cycle of operation being approximately 40 seconds. The outlets on the distributor are connected to the various cells so that the order of their inflation and deflation presents a minimum disturbance to the flying characteristics of the airplane.

g. A de-icer shoe is made of soft rubber and consists essentially of an inflatable tube area through its central portion, bordered by elastic zones, the outer margins of which are attached to the airplane. On the wings the inflatable area consists of parallel tubes, each from 1¾ to 3 inches wide in the flat or deflated condition. These tubes may be straight or tapered, depending on the contour of the wing. For the wings, three or more such tubes and their respective stretch areas are required, sometimes separated upon sections. The tail group

de-icer on small airplanes makes use of a sine-curve tube (two separate tubes manifolded together and separated by a scalloped or sine-curve seam). The empennage surfaces of the larger airplanes are fitted with de-icers similar to those used on the wings. Figure 54 shows a section of these shoes in the inflated and deflated condition.

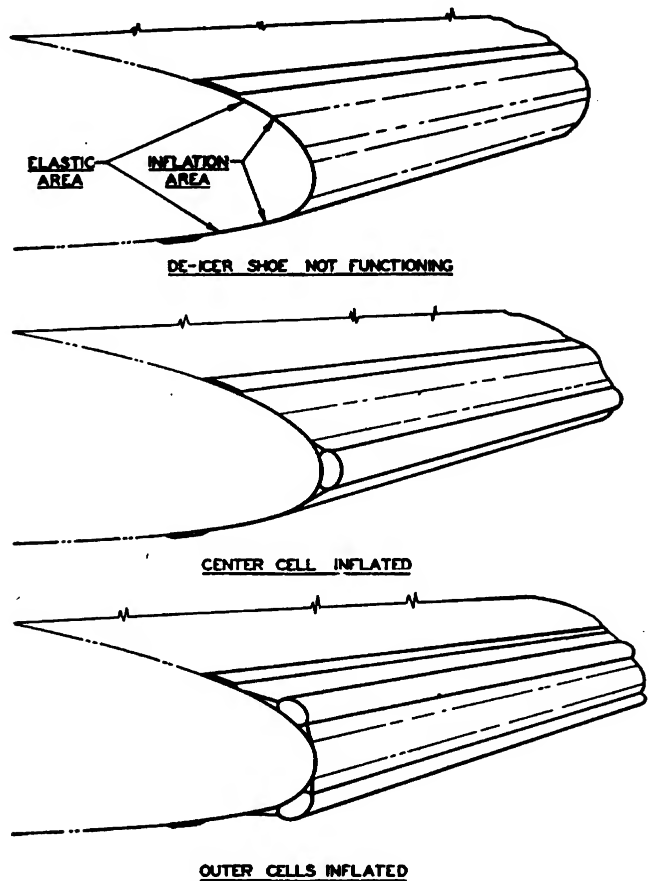

FIGURE 54.—De-icer shoe.

53. Operation.—*a.* A de-icing system employing a three-way control valve is placed into operation by starting the distributor valve motor and setting the three-way valve so that the air from the exhaust side of the vacuum pump is directed through the air filter and the distributor valve. In stopping the operation of the de-icing system the three-way control valve is set to bypass the air from the vacuum pump overboard instead of through the system. The distributor valve motor is stopped by opening the distributor valve motor switch only after the valve has been allowed to operate an additional 2 or 3 minutes and the air is completely expelled from the cell.

b. The de-icer system for multiple-engine airplanes (fig. 55) has two vacuum pumps and oil separators. Check valves are placed in the lines between the separators and the manifold to connect the output of these pumps to the system. These assure system pressure from either pump in case of failure of the other. In some cases the simple de-icer system is further modified as shown in figure 56. In this case a four-way control valve is employed and the vacuum line of one of the pumps is selected through a selector valve to give a more positive deflation of the boots. In the on position the system control

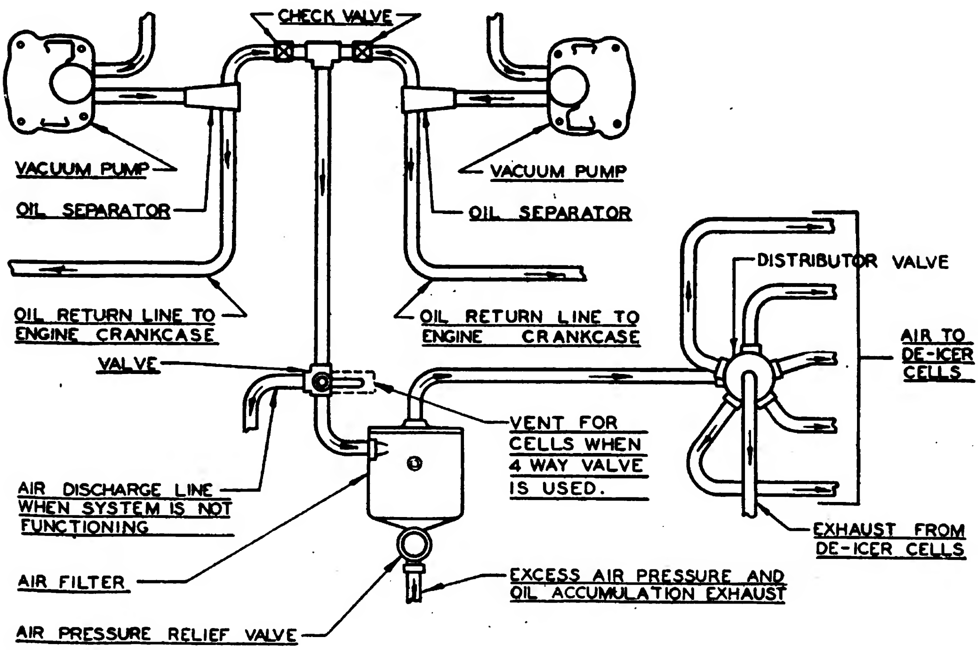

FIGURE 55.—De-icing system for multiple-engine airplane.

valve connects the pressure side of the vacuum pumps to the pressure inlet of the distributor valve and closes the electric switch to operate the distributor valve motor. In this position the vacuum line is connected to the discharge side of the distributor valve, giving a more positive deflation of the shoes. In the off position the control valve connects the pressure side of the pumps to an overboard vent, the electric switch is open, and the distributor valve motor is stopped. The vacuum line in this case is connected to both sides of the distributor valve to complete the application of vacuum to all the boots and insure their lying flat when not operating.

54. Maintenance.—De-icer shoes form a part of the contour of the airfoils on which they are installed, and the aerodynamic characteristics of the airfoils may be seriously affected and a distinct flying

hazard produced, should any rupture of the rubber take place in flight. Careful and frequent visual inspection must be relied upon to determine the extent of continued serviceability. Repairs of punctures are made by patches and cement supplied for this purpose. Gasoline may

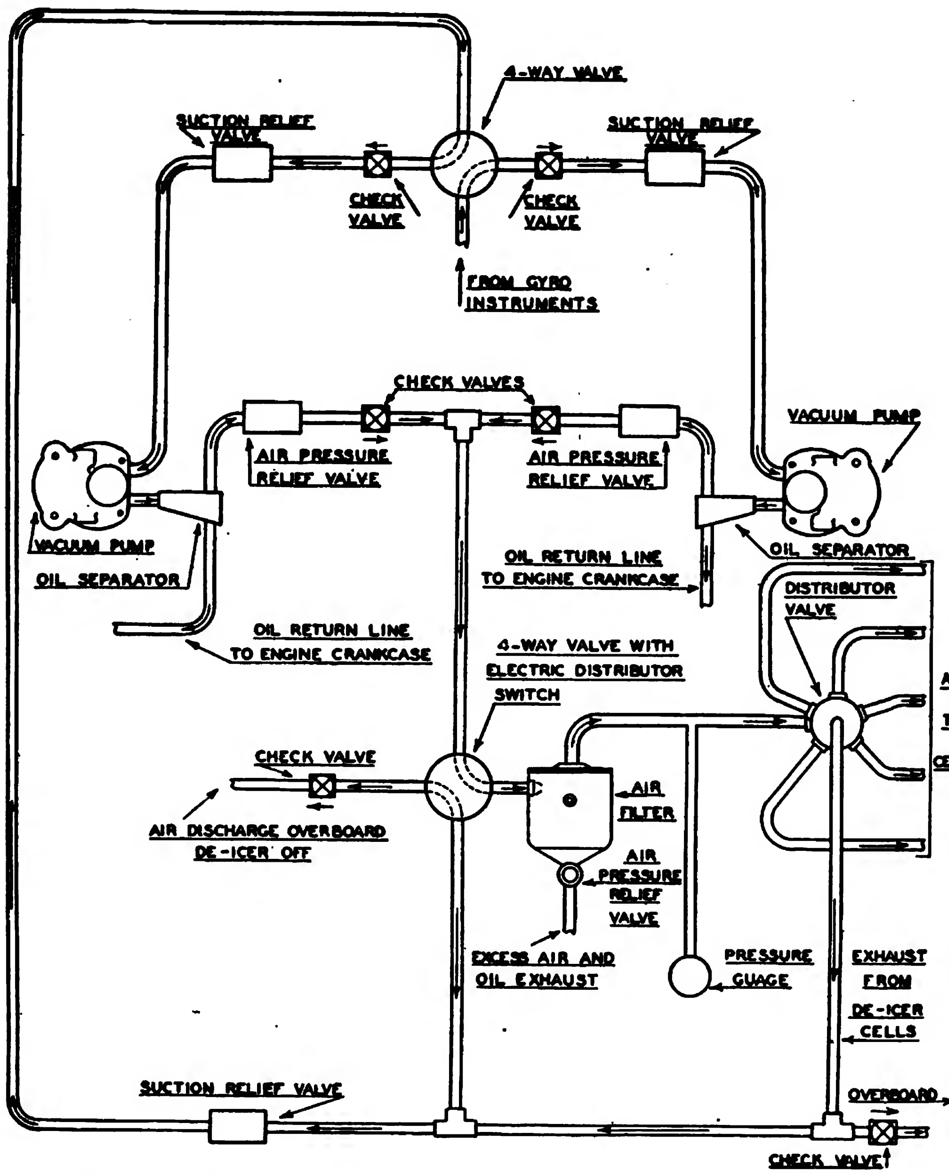

FIGURE 56.—De-icing system for multiple-engine airplane employing vacuum deflation.

be used to remove engine oil from the de-icer boots, but it should be wiped dry at once with a clean rag and not allowed to evaporate. The de-icer shoes may be washed with soap and water as a part of the regular cleansing of the airplane. In no case is the polished dark

brown or black surface that develops on the de-icer shoes to be removed except for the purpose of applying a patch. Since de-icer shoes are made of soft flexible rubber that is easily punctured, care must be taken not to drag heavy gasoline hose over the shoes or to lean maintenance ladders or platforms against them unless the ladders are fitted with sponge rubber pads at the points of contact with the shoe. After flights during which the de-icer boots have been operated and previous to servicing the airplane, metal chains reaching to the ground are placed in contact with each rubber boot to draw off any possible static charge.

Section X

HEATING AND VENTILATING EQUIPMENT

	Paragraph
General	55
Description	56
Operation	57
Maintenance	58

55. General.—Heating and ventilating of cockpits, cabins, and compartments of airplanes are accomplished by the use of hot-air systems, the source of heat being the exhaust manifold of the engine. In general, the systems may be classified as those in which the air is heated immediately at the exhaust manifold and those which employ an auxiliary steam system to transfer the heat from the exhaust stack to the cabin. The first type is generally used on the smaller type airplanes, e. g., attack, pursuit, and basic combat, while the larger airplanes usually employ the second and more elaborate heating and ventilating system.

56. Description.—*a.* In the simpler type system, a shell is mounted about a section of some part of the exhaust manifold and the hot air thus provided is led away through a tube and admitted into the cockpit or cabin through a valve controlled by the pilot or passenger. Usually such control incorporates a means of directing the flow of incoming air to different parts of the cockpit or cabin at the discretion of the occupant. Ventilation is usually provided for by ventilating ports opening to the outside and equipped with controllable deflectors. Ventilating ports are so arranged that fresh air may be admitted direct to the cabin without going to the heater.

b. The heating and ventilating systems of the second type consist of two separate and distinct sections: an air-duct system which supplies, controls, and distributes the air used for heating and ventilating and a steam-generating system which serves to transfer the

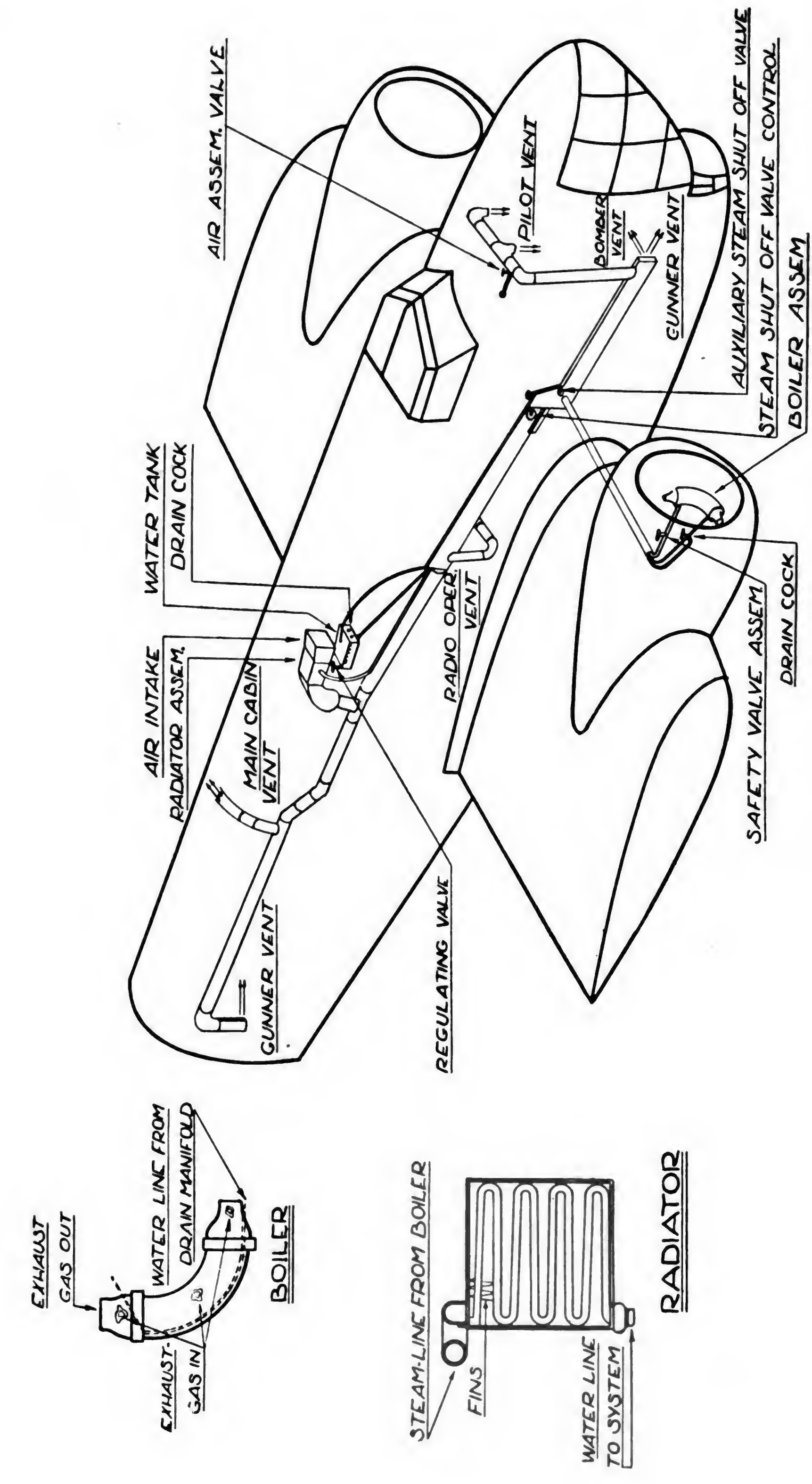

Figure 57.—Typical heating and ventilating system.

heat from the exhaust manifold to the incoming cold air. A typical system of this type is shown in figure 57.

c. An air-duct system is made up of the following:

(1) An air-scoop opening forward into the air stream. It may be of the fixed or adjustable type.

(2) An induction or cold-air duct which conducts the air from the scoop to the radiator, and which in some cases includes a by-pass duct around the radiator.

(3) A radiator in which the air is heated by passing over steam-heated surfaces. (A more detailed description of this unit is included in the discussion of the steam system.)

(4) The distributor or warm-air ducts which conduct the heated air to the various compartments of the airplane.

(5) The air controls which control the rate of flow of the air in the various ducts. These may be either of the damper or the sliding-gate type. In general, a cold-air control is contained in the induction duct to regulate the supply of cold air to the system and individual air controls are located in the separate distributor ducts to control or shut off the supply of hot air to the various compartments, e. g., cabin, cockpit or defroster. When a bypass around the radiator is used, an additional control is usually incorporated to regulate the relative amounts of incoming air going through and bypassing the radiator.

d. The steam generating system may be one of several types, each having a slightly different method of operation and control, but all depending on the same basic principles and having the same basic units. The units essential to all steam-generating systems are the water-supply tank or reservoir, the steam boiler, and the radiator or condenser. These units are described below in detail.

(1) The water-supply tank or reservoir, as its name implies, is a unit used to contain the supply of water for the steam-generating system. It may be a sealed chamber designed to hold steam and water at pressures above atmospheric or merely a container with a filler neck to hold water at atmospheric pressure. In some installations a gage glass for water level and a pressure gage for tank pressures are included with this unit. Reservoirs are equipped with connections for piping to the other units used in the system and in some cases employ a drain cock.

(2) The boiler is a unit used to generate the steam by passing the exhaust gases from the engine over a number of seamless tubes containing water. It is located in the engine section of the airplane and in most cases forms a section of the exhaust-collector ring. Because

of its high melting point and heat-resisting properties, inconel steel is used throughout in the construction of this unit. In general it consists of a circular-tube casing containing a number of small seamless tubes manifolded internally at the top and bottom of the casing, so that there are only two external connections; a water inlet located at the bottom and a steam outlet located at the top. The construction of the several types used in these systems is similar, the principal difference being in the size and shape of the boiler casing and the number and size of the internal tubes. A condensate return from the steam duct to the water supply line may be internal or external to the boiler.

(3) The radiator or condenser is used to transfer the heat from the steam to the incoming cold air in the air system. It is the one unit which is common to both the air duct and steam generating systems and in general consists of a brass casing containing either a number of coiled copper tubes manifolded internally at the two ends of the unit, or a copper honeycomb. One end contains a fitting for connection to the steam duct from the boiler while the other end contains one or two fittings for connection to the water return system and in some cases a steam trap or water regulating valve. When a steam trap or water regulating valve is incorporated in the system, only water is allowed to pass from the radiator to the return lines and all the steam is condensed in the radiator. Fins of thin copper sheets run between the tubes to aid in the conduction of heat from the steam in the tubes to the incoming cold air passing through the casing.

e. Since, as previously mentioned, the steam generating system may vary in details, the complete description of only one typical system will be presented here. The additional units included in this system and not previously described are as follows:

(1) A steam safety valve which is located on the steam duct. It is spring loaded and automatically limits the pressure in the system to a given value.

(2) A water shut-off valve which controls the amount of water passing into the boiler. The temperature of the warm air can be changed by allowing more or less water to run into the boiler.

(3) An auxiliary steam shut-off valve which is located forward and below the main shut-off valve. It is controlled by a push-pull rod and is of the butterfly type. This valve should be used only in case the relief valve in the bypass line fails to seat or does not function properly and allows the water to continue to run into the boiler after the main shut-off valve is closed.

(4) A water regulating valve or steam trap is located between the radiator and the water tank. It is a float type valve and allows the water to pass into the supply tank outlet line without the loss of any steam.

(5) A diaphragm type air valve located in the radiator return line is used to allow the elimination of air from the steam system. However, it will automatically close when the hot steam comes in contact with the diaphragm.

57. Operation.—The operation of this steam-heating system is as follows: When the water shut-off valve is opened, the water from the supply tank runs into the boiler tubes where the heat from the exhaust gases passing through the boiler casing converts it into steam. The steam is conducted through a steam duct to the multiple coils in the radiator, forcing the air in this part of the system through the diaphragm type air valve to the overboard vent line. The incoming cold air circulating about these coils absorbs heat from the steam which condenses and returns through the water regulating valve to the water supply section of the system. The hot air passes from the radiator through the distribution or warm air ducts into the compartments of the airplane as determined by the various air controls. The safety relief valve controls the operating pressure of the steam system and opens at a predetermined value.

58. Maintenance.—At regular periods or when required, steam ducts are re-covered with approved materials. If the airplane is to remain idle and be subjected to freezing temperatures, the entire water system is drained. Precautions must be taken that none of the engine exhaust gases get into the cockpit or cabin through the heating and ventilating system. Small cracks may develop in the exhaust manifold in the section surrounded by the heater shell, which may allow poisonous gases to be drawn into the cockpit with the fresh air.

Section XI

AIRCRAFT PARACHUTE FLARE

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59. General.—*a.* The purpose of an aircraft parachute flare is to provide sufficient illumination over a sufficiently large area, that a landing can be made at night.

b. Flares are considered as flames having the same candlepower in all directions. The factors affecting the visibility from aircraft of ground objects lighted only by flares may be classified as follows:

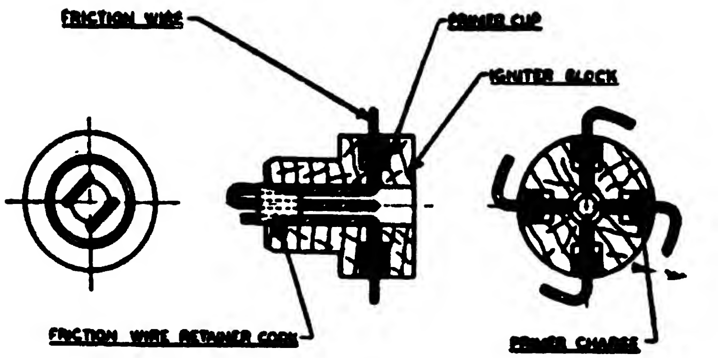
(1) Candlepower of the flare and number of flares used.
(2) Height from which the flare is released.
(3) Nature of the terrain reflecting the flare light.
(4) Condition of the atmosphere.

The parachute is not considered as contributing to any of the illumination on the ground.

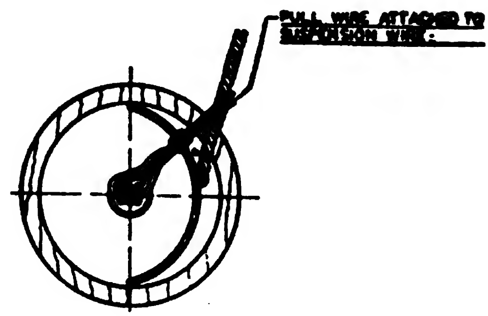
c. The altitude at which the flare is released affects considerably the ground illumination obtained from a given flare. The effective light area on the ground is circular in shape, with a diameter of approximately 6,000 feet at altitudes of from 1,000 to 3,000 feet. The area so lighted is approximately 1 square mile. Since objects on the ground are made visible by the light they reflect and by contrast with surrounding objects, landing fields being somewhat barren have a relatively higher reflection value so that other fields and wooded areas require a greater intensity of light and flares dropped over such areas must be at lower altitudes, or more than one flare must be in the air at the same time for good vision. The intensity of illumination necessary also depends on the condition of the atmosphere, that is, amount of haze, clouds, etc.

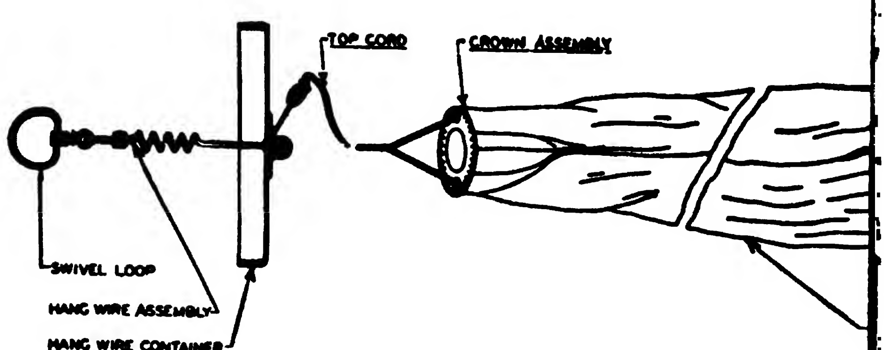
d. The maximum intensity of ground illumination will be obtained when a flare is released at between 1,000 and 2,000 feet altitude if the diameter of the circle of illumination on the ground and the average intensity of light are both considered; however, since the average time of burning is about 3 minutes and its rate of descent is about 600 feet per minute, to allow sufficient time for the flare candle to burn itself out while still suspended in the air, the minimum safe altitude is considered as 2,000 feet. This eliminates the fire hazard existing when the candles are still burning after reaching the ground. The maximum speed at which it is safe to release flares is 135 miles per hour.

60. Description.—*a.* The aircraft parachute flare, shown in figure 58, is cylindrical in form and consists of the parachute case assembly and the illuminant assembly. The parachute case consists of a metal tube, closed at the upper end by a cover which is attached to the case by means of the tear strip assembly. The hangwire container assembly is located immediately beneath this cover and is held in position by a shoulder formed in the case and sealed by wires passing through the edge of the container and case. The ends of these wires are twisted together and secured by soldering.



IGNITION BLOCK ASSEMBLY





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The space in the parachute case immediately below the hang-container is filled with the top cord, parachute, shroud assembly, suspension wire in the order named. The remaining 2 inches pace below the second shoulder is occupied by the upper end ne illuminant assembly. This is inserted as far as the shoulder permit and fastened in place by four wood screws.

The illuminant assembly consists of a cardboard cylinder 15¾ es long entirely filled with illuminant with the exception of a re- in each end of the cylinder and a center tube of cardboard in h the quick match is located. The large recess in the upper of the cylinder contains the base block assembly. The recess in lower end is empty and provides an air space around the lower of the quick match. The lower end of the recess is closed by body cover assembly.

Following are some descriptive data about the current type flare:

Length	25½ inches.
Diameter	4½ inches.
Weight with suspension bands	17½ pounds.
Weight without suspension bands	16¼ pounds.
Burning time	3 minutes.
Candlepower	300, 000.
Rate of descent	600 feet per minute.

Racks.—(1) Flares may be carried on aircraft in either the hori-al or vertical position. Of the several type racks used to carry s in the horizontal position the type most used is installed en-y within the wing of an airplane. The opening in the lower sur- of the wing is closed by a spring retainer door. The door is ned by the flare release cable 20° ahead of the release of the flare nsure positive egress of the flare. The door is opened mechani-y to break the sheath of ice which forms on the under surface he wings under certain weather conditions. The rack consists of carrying hooks pivoted in the frame, linked together, and re-d simultaneously by a releasing latch at the forward end. The ing wire swivel loop is attached to a snap hook fastened to the t end of the flare rack. When flares are to be carried in a hori-al position, the suspension bands are installed on the flare body, ed 14 inches apart, as shown in figure 58, to support the flare he racks. Black bands are painted around the flare cans at the tions for these suspension bands. There are also short, black s painted parallel with the longitudinal axis of the flare for ting the loops on the suspension bands.

(2) Racks used to carry flares in the vertical position in most general use consist of a cylindrical guide chute closed at the bottom by a carrying and releasing door on which the flare rests when installed. The top of the chute is covered by a hinged lid in which the hangwire swivel loop of the flare is held by the loop-retainer plunger. The lid is fastened by a spring latch and covers the chute to prevent the entrance of water, etc. The carrying and releasing door is a component part of the flare rack, but the latch plate in which the door latch engages is furnished by the airplane contractor to suit installational requirements. The rack may be loaded from either the top or bottom, depending upon the overhead and ground clearance available.

(3) A flare-release handle is used to release the various vertical and horizontal flare racks. One handle is used with each rack and the cables connecting them are provided with a return spring to retract the handle after release and to provide the ½ inch slack necessary to remove all tension on door release and rack-release mechanisms.

61. Operation.—The operation of the flare is the same whether carried horizontally or vertically. When the mechanism carrying the flare is released, the flare falls to the full length of the hangwire, pulling the hangwire container out of the parachute case, following which the top cord, the parachute (closed), the shrouds, and the suspension wire are withdrawn. As the entire weight of the illuminant assembly comes on the tear strip to which the top cord is attached, the strip is broken and the parachute falls free and opens. At approximately the same time the weight of the illuminant assembly on the parachute and its suspension wire draw the pull wire to which the friction wire loops are attached out of the upper recess in the illuminant assembly. This withdrawal of the friction wire through the primer charge causes ignition of the quick match which projects into the space around the ignition block in the base of the base block assembly. The quick match burns down through the long center cardboard tube in the illuminant assembly and ignites the first fire charge carried in the base of the illuminant case. This burns out the lower disk and the lower rim of the illuminant case, freeing the body cover assembly from the case. The main body of the illuminant is ignited by the first fire charge and burns steadily upward as the flare descends.

62. Maintenance.—*a.* Flares installed on aircraft are always carried armed, that is, with the hangwire swivel loop properly anchored. This is to prevent the flare assembly being accidentally dropped without burning, which is extremely hazardous in populous areas. Although constructed so as to be practically waterproof under

normal conditions of use, flares should not be exposed unnecessarily to dampness. Unless the installation is such that the flares are properly protected in airplanes that are not stored in the hangars, the flares are removed and properly stored during damp or rainy weather. Proper notation is made to the effect that the flares have been removed so that the pilot is aware of the fact before the airplane is flown.

b. At the time of installation of flares in the flare racks, and at periodical inspections, the operation of the racks and release mechanism is checked by installing the flares without securing the hangwire swivel loops and then operating the release mechanism. When this check is being made, someone is stationed beneath the airplane to catch the flare before it strikes the ground. Where desired, this test may be accomplished by substituting a dummy flare of approximately the same weight, diameter, and length as the flare; however, the flares to be installed in vertical flare racks following this test are then tried in the rack to ascertain whether binding occurs at any point. If binding occurs, other flares will be tried to secure one that will slide freely in and out of the chute. Care is taken in handling flares that the carrying hooks are not bent and that the flare body is not dented or otherwise damaged.

c. The premature release of flares when taxiing over the ground may cause the flare to strike the ground without pulling of the hangwire container. In this case the bottom of the flare will be dragged over the ground until the bottom covering is torn off, exposing the ignition elements. As these elements are readily ignited by friction, ignition of the candle and subsequent burning of the airplane may result either before or after the airplane has left the ground. Under these conditions it is impossible to release the burning flare from the flare rack by operating the controls, since the flare is suspended by the hangwire, which in turn is secured to the rack. Only by exercising the utmost care and checking all parts of the flare rack and the flare installation can prevention of premature release and malfunction of flares be assured.

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BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
Major General,
The Adjutant General.

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